MORTON'S HAND BOOKS of the FARM

Nº VIII.

ANIMAL LIFE.

BY

PROFESSOR BROWN.

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HANDBOOK OF THE FARM SERIES.

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EDITOR OF THE "AGRICULTURAL CYCLOPÆDIA;" THE "AGRICULTURAL GAZETTE," THE "FARMER'S CALENDAR;" THE "FARMER'S ALMANAC," ETC.

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BY

GEORGE T. BROWN,

AGRICULTURAL DEPARTMENT, PRIVY COUNCIL.

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The present Volume is one of a series discussing the Cultivation of the Farm, its Live Stock, and its Cultivated Plants, Farm and Estate Equipment, Dairying, and Farm Labour, the Chemistry of Agriculture, and the Processes of Animal and Vegetable Life. Among the writers who have been engaged on them are Messrs. T. Bowick, W. Burness, G. Murray, the late W. T. Carrington, the Rev. G. Gilbert, Messrs. James Long, J. Hill, Sanders Spencer, and J. C. Morton, Professors G. T. Brown, J. Wortley-Axe, and J. Scott, the late Professor James Buckman, Dr. Maxwell T. Masters, F.R.S., and Mr. R. Warington, F.C.S.

PREFACE.

For this Volume, which, whatever the order of their publication, is properly the last of any series professing to cover the agricultural field, we are indebted to Professor G. T. Brown, the Professional Head of the Agricultural Department of the Privy Council, whose long experience, both as student and as teacher of the whole class of subjects here treated, eminently qualifies him for the task he has undertaken. An Index and a Glossary of scientific terms will be found at the end of the book.

J. C. M.

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LIFE ON THE FARM.

ANIMAL LIFE.

INTRODUCTION.

LIFE—and its negation, death—are subjects which have puzzled the wise people of all ages. What is life? is a question which the Sphinx might have put to Œdipus with the certainty of not getting an answer; and the same question even in the present day fails to call forth a reply which satisfies the inquirer. Perhaps no answer can be given which would: all that we can say about life is that it is the sum total of the actions which are always going on in living beings. Or, if the reader prefer Mr. Herbert Spencer's philosophical definition, life is—"The definite combination of heterogeneous changes, both simultaneous and successive, in correspondence with external co-existences and sequences." This answer may do for the modern biologist; it would not have saved Œdipus from the Sphinx.

Living things are quite apart from things which are not living. Mr. Huxley tells us that science knows no link between them. It is not a question of beauty of form or delicacy of structure, or intricacy in the arrangement of parts. In all these a crystal may be above a plant or an animal, but the animal or plant is alive, the crystal is not; and between these two states there is a gulf which no one has yet been able to bridge.

Life does not arise as the result of the union of particles of non-living matter under certain conditions of heat, light and electricity; nor is complexity of organisation essential for its development. Even in its small beginnings, life is only to be seen as an outcome of pre-existing life.

A little world, so small as to be unseen by the unaided eye, is open to the observer with the microscope. In this little world life is seen in its most simple form: the living thing, a mass of jelly (bioplasm), may belong either to the animal or plant kingdom. The clear jelly can move, in fact does send forth arms and legs, and draw them in again, and by-and-by resolves itself into most fantastic shapes. But more than this, it can feed, and breathe, and carry on its circulation without stomach, or lungs, or heart, doing all quite perfectly and without effort by merely taking advantage of the state of life in which it finds itself; imbibing the fluids in which it lives, using all that is useful and rejecting what is unfit for its support, growing day by day, and now and then sending off small masses from itself which break away and become new and independent beings. Finally, it becomes worn out, and in the common course of things dies, aud undergoes solution in the water in which it has lived; unless, haply, the term of its calm life is cut short by some other animate thing, a little higher in the scale than itself. Thus the living jelly seems, in its little world, to be a parody of the living being in the greater world. It lives, grows, assimilates food, reproduces its kind, gets worn out at last, and pays the penalty of being by falling into the state of being not.

Higher up in the life grade, bioplasm gets a definite form, and is surrounded by a membrane or cell-wall. Cells so formed unite together or become long or flat or otherwise changed, and so form organs and tissues; and living things thus built up can now be classed as animals, or plants having certain characters which separate them from each other, but also many which connect them together; so many, indeed, that Mr. Francis Darwin has given us a fairy story about the "Analogies of Plant and Animal Life," more wonderful, because more true, than any of the thousand and one stories of the "Arabian Nights."

Plants, or parts of them, can move about from place to place. Some of them take care of their young quite as well as animals do. Others show likes and dislikes, go to sleep and awake. Many are very sensitive, and some seem to possess instinct and memory—qualities which have in our ideas been limited to the members of the animal kingdom.

Mr. Francis Darwin ends his story in these words, which are worth noticing:—"I have tried to show that a true relationship exists between the physiology of the two kingdoms. Until a man begins to work at plants he is apt to grant to them the word 'alive' in rather a meagre sense. But the more he works, the more vivid does the sense of their vitality become. The plant physiologist has much to learn from the worker who confines himself to animals. Possibly, however, the process may be partly reversed—it may be that from the theory of plant-physiology we may learn something about the machinery of our own lives." Animals, from the lowest to the highest, differ from plants chiefly in their powers of digesting and assimilating food, and in this matter the advantage is, in some respects, on the side of the plant.

To make this point quite clear it is necessary to state that all living beings undergo waste; every movement causes the loss of some part of the structures. This waste is made good by the food on which the being lives being changed into the tissues of the animal or the plant. This process is called "assimilation." Living or organised beings may be resolved into a few elements,* about a dozen, of which the principal are oxygen, hydrogen, carbon, nitrogen, sulphur, and phosphorus. All these are united to form the tissues which are distinguished as albuminoid, and the first three to form tissues which are non-nitrogenous. Food must contain the elements of which the organism is made up: but now occurs the very great difference in the requirements of animals and plants in regard to the way in which the elements must be arranged so as to form food which can be assimilated or changed into their own structures.

Taking the animal first, we know, without trying the experiment, that it cannot live on the elements of which its structures are built, unless those elements have been joined together in some way so as to come very near to the actual tissues which are to be repaired. The animal body demands that its albuminoids and fats be ready made before it can make good use of them; and if, instead of giving them in this form, we offer the elements of which they are made, the animal dies of starvation, in the presence of an abundance of oxygen, hydrogen, carbon,

* See "Chemistry of the Farm," by R. Warington. Bradbury, Agnew, & Co.

and nitrogen, with sulphur and phosphorus, which its organism can receive but is quite unable to use in their elemental form.

Exactly at the point where the animal fails the plant triumphs. Food in the most simple form is what it is most capable of using. Nitrogen and hydrogen it can get from ammonia, carbon and oxygen from carbonic acid; in fact, the elements which are necessary for its organism are taken from the air, water, and soil, and united together to form the albuminoids and non-nitrogenous compounds which are necessary to supply the animal kingdom with food. Plants, indeed, can assimilate inorganic substances and change them into organic and living matter; animals cannot assimilate inorganic substances, but must wait until plants have done the work of organisation for them. Animal life therefore depends on plant life, and in the scheme of the universe the "herb yielding seed" is the basis of organisation.

In the following pages the object of the writer is to explain in simple terms some of the actions which are going on in the organism of the higher animals, and particularly of the animals which form the Stock on the Farm. Books on the subject of biology are numerous and to the scientist endlessly interesting, but the writer of this book cannot advise the reader for whom it is intended to plunge into the mysteries of biogenesis. He can, however, advise him to study the preceding Handbooks, especially the one on Plant Life, as a preparation for the reading of this, which, as stated in the Preface, comes properly in its place as the latest of the series.

CHAPTER I.

BEGINNINGS OF LIFE.

How Animals are Formed, and how they Grow—Necessity for Division of Labour in Scientific Work—Limits of the Present Inquiry—Structure and Changes of the Serum—Development of the Embryo—Growth—Nutrition—Sketch of the Various Processes of Waste and Repair of the Structures of the Animal Body—Selective Power of Tissue—Secretion—Excretion.

ANIMAL Life on the Farm is a title which covers a good deal of ground. And it may be well to state at once how much of the field is to be explored. On a farm of very limited size, the scientific inquirer might easily find work to last him for life, and yet leave a vast amount unfinished. Indeed, the owner of such a happy hunting ground must be a very accomplished person if he undertake to touch the confines of all the subjects which would be presented to his notice. As a geologist, he would delve into the earth in search of rocks and beds. As a chemist, he would follow out, in the laboratory, the work of analysis. Then coming to the living things, he must assume the functions of the botanist, to work out the history of Plant Life ; and in dealing with Animal Life on the farm, he would play the parts of entomologist in examining and classifying insects : as an ornithologist, he would devote his attention to the structures and habits of birds; and as a physiologist, he would have to study all the phenomena of life. In fact, if any one scientist started with the idea of doing all the scientific work which could be done on a farm, he would soon find it necessary to take with him several other people as clever as himself, and assign to each his special work. This reasonable course has been adopted in the preparation of the series of Handbooks, of which this is to be the completion; and it remains for the writer to limit himself mainly to that section of the subject of Animal Life on the Farm which refers to farm animals proper—that is to say, horses, cattle, sheep, and swine. Much that will be written may be applied to all living things, but in working out details of vital processes, it will be an object to bring all the facts as far as possible to bear on those animals with which the farmer has most concern.

It will be interesting as well as convenient to introduce the subject of Animal Life by a glance at the changes which occur in that wonderful body which is called an "egg" or ovum; out of which it is said all living things come. A bird's egg is the best example of the "ovum," because it is large enough for its parts to be seen without the aid of any lens. The ovum of the mare or the ewe differs from that of the bird chiefly in its extreme minuteness—and it may be said that the eggs of all animals are much alike, except in the matter of bulk.

Taking any egg as a sample, it may be seen that the several parts are the yolk with its investing membrance—and the minute cell or germinal vesicle, which is placed at one part of the circumference of the yolk. The shell of the egg of the bird and the part called the white need not be specially noticed, as they are not essential parts of the typical ovum. The first thing to be noted in regard to the ovum is that it contains a small mass of living material

—the germinal vesicle in which the vital processes commence which result in the formation of the embryo.

Development.—When an egg of a bird is held in the hand there is nothing to indicate that it is alive, but it is only necessary to keep it for a short time at a temperature of something like a hundred degrees of Fahrenheit's thermometer to prove that it must have been alive, as the moderate heat of the incubator could not have originated life in the creature which emerges from the egg. Birds' eggs are not transparent, and the changes which occur during hatching can only be seen by taking eggs from the sitting bird or from the incubator at fixed hours and opening them ; but the eggs of some animals—aquatic molluscs, for instance—are transparent, and the process of evolution or development of the embryo can be observed in them under the microscope with perfect ease.

From actual observation of the changes which occur during the period of incubation or hatching, it is certain that the following account of the formation of the organs and structure of the embryo in one of the higher animals, say a mare or a cow, is strictly accurate.

The germinal vesicle is the seat of the first changes which occur. As the ovum becomes mature, the germinal vesicle gradually fades away and gives place to a single cell which is a mass of bioplasm or living jelly inclosed in a cell-wall. As soon as the egg is placed under favourable conditions, after being rendered fertile by contact with the sperm-cell of the male, other changes begin. The mass of bioplasm shows living activity by dividing into two, four, eight, sixteen, and then an indefinite number of parts. The yolk undergoes division at the same time, and at length a mass of spherical bodies is formed, which is known as the mulberry mass.

The cells forming the mulberry mass pass to the circumference of the yolk-sac, and form a continuous layer in the inner surface of the membrane. Then the cells accumulate at one point which is the centre in which the embryonic tissues are to appear, and is therefore described as the germinal area. It may be remarked that the membrane in which the germinal area is formed is composed of two layers, an upper or outer "serous layer," and an inner or lower "mucous layer;" a third, or "vascular layer," is added after a time.

Soon a clear space appears in the midst of the germinal area, and in this clear space the rudiments of the young animal begin to arrange themselves. First the foundation of the brain and spinal cord is laid, and then off-shoots of the membrane proceed downwards to form the walls of the chest and abdomen. From the inner layer of the germinal membrane and part of the middle one the organs of the chest and abdomen are formed, the middle one forming the bulk of the internal organs. Limbs are formed by outgrowths of the germinal membrane, the middle layer forming the bones and many of the soft parts. In their early state the limbs are only small knobs on each side of the trunk. As they increase, the different segments appear, and the divisions of the terminal parts of the extremities are marked out and completed.

Growth of the Fœtus.—From the time of the fixing of the type of the structures of the young animal by the process of development, the stage of growth—that is, the increase in bulk of organs and parts which are already formed—begins, and goes on until the young one is sufficiently advanced to be removed from the uterus of the mother, and lead a separate existence. This separation is effected in the act of parturition.

Nutrition.—When the young animal is separated from the organism of its mother it brings into use organs which were in an inactive state while it remained in the uterus, where the principal function was the circulation of the blood, which supplied the materials out of which the tissues were formed. Now, in the outer world, it has to obtain food of a different kind, and use it in a different way. It is required to breathe in order to get oxygen to burn up the superfluous carbon in its body and keep up heat, which it no longer derives from its mother. While performing these functions it moves from place to place, and its excretory organs, which were of little use while it was in the fœtal state, are now actively at work. The sum of all this is loss of material in many ways—by friction during motion, by oxidation, and by excretion; and yet, in spite of this, the young animal grows.

It is hardly necessary to tell the owner of farm stock that the process of repair in the system of the young growing animal is more active than that of waste, because the fact is evident. He knows that the time will come when the two actions will be about equal; and, at last, the wasting process will be so active that it will be difficult and not always possible for the repairs to be done fast enough to keep pace with it; but he does not know, and no one can tell him, the why and wherefore, except by saying that there is more vital energy in the young animal than in the adult and the aged; which is very much like reasoning in a circle.

In order that young animals may have the full benefit of the power which they possess to appropriate food it is necessary that the amount and kind of aliment which the system requires should be supplied. This very patent fact is not by any means universally admitted, or at least, it is often lost sight of in practice. Young stock, we are sometimes told, can be kept on short allowance until a few months before they are to put up to fatten. The scientific breeder knows very well that there is no economy in such a system. The whole secret of early maturity, of which more anon, lies in taking advantage of the remarkable aptitude shown by young stock to assimilate food and grow thereby.

Selective Power of Tissue.—In connection with the function of nutrition as opposed to waste, it is necessary to notice the peculiar power of selection which is present in the tissues, enabling them to take from the blood exactly what they require and reject all that is foreign to their own structure. This quality, which in a single organism would be called an "instinct," is, in regard to its effects, so well known as to pass unnoticed. But its real importance will appear if a moment's thought be devoted to the process.

Blood in circulation contains in solution, or in suspension, all the materials which are necessary for the repair of the numerous structures of the body—bone, muscle, fat, tendon, nerve, gland, skin, horn, and hair. No separation of the different compounds which the blood contains can be effected in the vessels; they only form the channels through which the complex fluid flows, and out of which its nutritive part is constantly leaking into the tissues, giving them a choice of various compounds, albuminoids, and fats, living and dead matter, but using no force to compel them to take them, always leaving the tissue to make its own election. Nothing can be more satisfactory than the results of this method of supply; each structure takes the materials which it wants and leaves what it does not require, to be carried farther on. If, however, by any chance the tissues should lose their selective power or use it perversely, this is what might be expected to happen:—One day the brain, instead of taking proper substances from the blood and using them rightly, might select fats and the elements of white fibre, and so form "a fibrous fatty tumour" in its centre. Some of the bones rejecting proper bony matter might take some of the albuminoids from the blood and construct a fleshy mass in their hard structure, which would be called by the pathologist "osteo sarcoma." The lungs or liver might choose brain matter and form deposits which would be called from their close resemblance to brain substance "encephaloid tumour." Various structures in the body might show a preference for bony matter, and the bone would crop up in places where it was least expected, as "ossific deposits."

If the reader should be disposed to look upon the above suggestions as merely fanciful and outside the region of possible facts, he is asked to believe that the illustrations are in no way strained; the words used express, in truth, exactly what does occur in the animal body when the nutritive functions of certain parts become deranged and the selective power is perverted.

Pathologists have long been aware that the elements of diseased deposits may be found in the healthy tissues.

Virchow announced the doctrine years ago, that in disease no new structures are formed, but existing structures are misplaced; in short, that the selective functions are perverted and certain tissues no longer take what is proper to them, but utilise the elements of other structures and suffer disturbance accordingly.

Secreting organs which are employed in separating from the blood which passes through them certain parts, both solids and fluids, for the purpose of expelling them from the system, or of sending them to other parts to assist in the nutritive process, show the power of selection in the highest degree. The liver selects the materials for making bile. The kidneys remove urea with water and certain salts. The salivary glands form saliva, and the perspiratory glands of the skin select the components of sweat.

The blood passing through the different organs contains the materials out of which all or any of the secretions could be formed. It might therefore happen that the kidneys or skin would secrete bile, and the liver or the skin separate urine from the blood; but the exercise of the power of selection prevents these unpleasant consequences while the organism is in a state of health; but they do happen under certain conditions, and from time to time, "vicarious secretion," as it is called by physiologists, occurs. When one organ—kidney, or liver, for instance—ceases to secrete—in other words, loses its power of selection—then its work is done, not so well, of course, by another organ. Sometimes the relief afforded gives the deranged organ time to recover, and all goes on as before; but instances have been known of permanent loss of function of the kidneys being compensated by the "vicarious" action of the skin.

Organs which have to do the work of secretion must really possess a double function of selection, as they have to obtain, from the blood, the materials for their own support, as well as those which form the particular secretion which is to be used for other purposes. For example, the udder is a large organ requiring a good deal of repair from time to time, having, indeed, a large supply of blood for that purpose; but while milk is being secreted, a much larger supply of blood is necessary for that special purpose, and the chief function of the organ is not to separate materials for its own support but for the support of its young, which for a time have no other source of food supply.

The liver is an organ of large size, having an extensive system of vessels and a large supply of blood, of which only a very small part is devoted to the support of the gland itself, the bulk of the fluid being sent for the liver to work upon and separate some of its constituents, which must be got rid of before the blood gets back to the heart again. The business of the liver is, in short, to secrete bile, and form a substance which is to be changed into sugar, and to do other things than merely looking after itself.

To all the secreting organs of the body the above remarks may be applied. The organs engaged in this work form a large part of the animal, indeed they are so numerous that they can scarcely be counted in the skin and in the mucous membranes of the digestive and respiratory organs; and they are all of them employed in the same useful work of separating noxious matters from the vital fluid, and in aiding in its purification or in selecting substances which are required for the performance of important duties in various parts of the organism.

It is usual in describing the function of a secreting organ to refer to the process of "*excretion*" as something which is distinct from the ordinary function of "*secretion*." There is, in reality, in a physiological sense, very little difference to be noted. When the materials which are separated from the blood are thrown off as waste products the process is described as "excretion." This differs from "secretion" only in regard to the final use of the results of the process. Urine, for example, is called an "excretion," because it is thrown off as useless or deleterious matter; but the kidneys have first to "select" and "separate" from the blood the urea and salts of which urine is composed, just as the salivary glands separate the constituents of saliva, which is a fluid having an important work to do in the process of digestion.

So far as the inquiry has gone, it appears that the process by the agency of which the structures of the body are kept in a state of repair is a complicated one; First, there is the destructive action which gives rise to the necessity for repairs being done, that is to say, waste; which is the consequence of the burning up of fatty tissue by union with oxygen, and the wearing away of structures, which is due to constant motion. Next, there is the supply of what may be called the raw material for repairs—the food, which has to be prepared in the digestive system, and finally assimilated by the tissues in the exercise of their power of selecting what they want and rejecting the rest. In the course of digestion various secretions are used for the purpose of setting up fermentation and thus causing the necessary changes in the compounds on which the animal feeds. Lastly, the waste materials are expelled from the body through the digestive system, the kidneys, the skin and the lungs.

The preceding sketch of the processes of waste and repair must be supplemented by a description, necessarily a brief one, of the apparatus which is used for the preparation and assimilation of the food, and in the almost equally important work of getting rid of the waste products; which cannot be allowed to accumulate without risk of serious damage to the animal machine.

CHAPTER II.

ORGANS OF DIGESTION.

The Digestive Organs in the Simple Form—Type Preserved in the Higher Animal—Mouth—Salivary Glands—Swallow—Stomach—Intestine—Liver—Pancreas—Digestion—Food—Digestion in the Mouth—Changes effected in the Stomach—Intestinal Digestion—Results—Absorption of Chyle—Action of Mesenteric Glands and Liver—Completion of Digestion in the Lungs.

Type of the Digestive Organ.—In its most simple form the digestive system consists of a tube, which passes quite through the animal body, having an anterior opening or entrance, and a terminal opening or exit. The tube is lined throughout with a secreting membrane, and is pierced here and there by the ducts of certain glandular structures, which send into the digestive tube secretions to aid in the process of digestion. In the higher forms of organisation the digestive tube is more intricate in its arrangement, and the glands in connection with it have a more definite form and function; but under no circumstances do the organs depart in any essential particular from this primitive type.

The Mouth.—Beginning with the anterior opening, or mouth, we find in the higher animals a perfect arrangement of structures for grasping and cutting or grinding the food. At the entrance of the cavity are the lips.

Strong bones form movable jaws which are acted on by powerful muscles. Teeth are set in the jaws in convenient positions to act on the food. Mucous membrane, with numerous glands and follicles, lines the whole cavity, and the centre is occupied by a muscular organ, the tongue, which is usefully employed in moving the mass of food about, keeping it within the range of the teeth, or assisting it in its backward course to the opening of the œsophagus.

Salivary Apparatus.—In various regions of the cavity of the mouth, but principally at the posterior part, extending from the root of the ear downward, and in the space between the two sides of the lower jaw, and also under the tongue, are placed large glands, in pairs, which secrete the saliva. Those which are situated farthest back are the parotid glands, one on each side. The ducts from these glands pierce the mouth opposite the second upper molar teeth.

Underneath the lower jaw are the submaxillary glands, the ducts from which enter the mouth near the tip of the tongue by openings which are well known from the little eminences which guard them (the barbs). Above the submaxillary glands there are placed between some of the muscles of the tongue, the two sublingual glands, which pour their secretion into the mouth through numerous little openings on each side the base of the tongue.

Besides the larger salivary glands there are several small glands placed near the roots of the molar teeth, between them and the cheek, and also under the mucous membrane of the lips, the base of the tongue, and the soft palate.

In structure all the salivary glands are alike. They consist of minute lobules of soft spongy tissue, joined together by fine fibres. Their tubes gradually unite to form larger canals through which the saliva enters the mouth. In common with all secreting structures the salivary glands are well supplied with blood.

Commencement of the Digestive Tube.—Behind the soft palate there is placed a muscular funnel-shaped pouch, the pharynx, which may be called the beginning of the digestive tube. From this pharynx the tube extends, under the name of the swallow (œsophagus) along the neck, to the entrance of the stomach. And here we have to pause a little in the general description, to point out certain details in regard to the form and structure of this important organ and of the intestine connected with it in the several animals of the farm.

Stomach and Intestine.—These organs are composed of three distinct coats—an external one of fibrous tissue, a middle coat of muscle fibres, and a lining of mucous membrane, in and beneath which are placed numerous glands, most of them having free communication with the interior of the digestive tube.

It has been stated that the digestive organs in the higher animals preserve the simple type of a single tube; the difference, in fact, is one of length and bulk. In the animals with which we are chiefly concerned the tube swells out in certain parts to form sacs, and its length necessitates many turns and coils in order to get it into the space which can be conveniently afforded for it in the cavity of the abdomen.

To form the stomach the digestive tube may be dilated into a single sac, or it may be expanded several times so as to form three or four sacs; but it is very necessary to note that it is only the single sac, or the last one of the several sacs, which can properly be described as a true digestive stomach, because its mucous lining membrane incloses the peptic glands which secrete the gastric juice.

The single stomach in the Horse and Pig is a pouch curved on itself in such a way as to bring the entrance and exit rather near together. The outer curve is called the "greater," and the inner the "lesser" curvature. In the interior of the stomach of the horse there is a peculiar arrangement of the mucous membrane, the anterior half being smooth and hard, while the posterior half is like velvet, soft to the touch. This portion only is the true gastric membrane which secretes the gastric juice.

Ruminants, like the Ox and Sheep, have the stomach divided into four sacs. First, the paunch or rumen, a very large organ, forming in fact nine-tenths of the whole, occupying a considerable space in the abdominal cavity, chiefly on the left side. Into this large pouch the œsophagus enters in such a way that all the food passes into it after being partially masticated, and acccumulates there until the animal feels disposed to return it to the mouth for further preparation. At the upper part of the rumen, and to the right of the entrance of the œsophagus, hangs a small sac, which, in consequence of the peculiar arrangement of its lining membrane in a reticulated or net-like form, is called the reticulum or honeycomb.

Another small sac, the omasum (or manyplies) is found next to the reticulum on the right side of the rumen. This sac has a very remarkable arrangement of the lining membrane in folds, or leaves, between which the food must pass in its course to the next compartment of the stomach.

The fourth stomach, abomasum, commonly called the reed or rennet, is larger than the two sacs between it and the rumen: in the sucking ruminant it is the largest of the four, but, as soon as the young animal begins to feed on herbage, the rumen continues to increase in bulk until it attains its full dimensions. In form, the fourth stomach is somewhat like a pear, but is curved slightly on itself, having the larger end towards the omasum. The lining membrane is soft and highly vascular, and is distinguished from the mucous lining of the other sacs by its function of secreting the gastric juice.

From the stomach the digestive canal continues as a long tube with many coils. At its commencement it is tolerably uniform in size, and for a great part of its length—about twenty-four yards in the horse and rather more than double that length in the ox—it is called the "small intestine." Afterwards the tube varies in size considerably, but is generally larger than the anterior part, and is called the large intestine.

The small intestine is suspended from the centre of the abdominal cavity by a fold of membrane, the mesentery, through which its blood-vessels and absorbent vessels reach it. The large intestine is held in its place by a similar arrangement. It is not perhaps a matter of much consequence to the reader who is not learned in scientific terms, but it may as well be noted that anatomists divide the small intestine into the duodenum, the jejunum, and the ileum; and the large intestine into the cæcum, colon, and rectum, which is the end of the digestive tube.

The Liver and Pancreas.—These organs do not form part of the digestive tube, but they are joined to it by the aid of certain small canals or ducts, which convey the secretions from the glands into the intestine.

Both liver and pancreas, or sweet-bread, are familiar to most people as articles of food. It is true that the proper sweet-bread is the thymus gland of the calf, commonly called "throat-bread," an organ which becomes "small by degrees and beautifully less" as the animal grows, and is, therefore, in its prime, an expensive article, but the sweet-bread of common life is supplied by the pancreas very often, and failing that by other glands of somewhat similar structure, and of like flavour.

The liver is the largest gland in the body, weighing in the horse about twelve pounds; it is elliptical in shape and is divided by deep fissures into three principal lobes. The gall-bladder, which exists in all farm animals excepting the horse, is placed on the posterior surface.

In its general aspect the liver is not unlike what its name implies, a clot of blood; the colour is dark red or brown, and the texture is soft; the surface is everywhere smooth and glistening. The liver occupies a position on the right side of the abdomen, between the stomach and the partition which divides the chest from the abdomen (the diaphragm). It is held in its place by the large vessels which pass into its structure, and by folds of membrane which are called its ligaments.

Internally the liver has a very perfect system of vessels and ducts for the secretion and conveyance of the bile, which is partly taken into the gall-bladder or directly into the first intestine (duodenum), but in all cases the fluid is ultimately destined to enter that part of the digestive tube.

The pancreas is placed in front of the kidneys, and its duct enters the first intestine with that of the liver by a common opening. In structure the pancreas is like the salivary glands, consisting of minute masses of soft spongy material joined together by fine fibrous tissue. The pancreatic fluid is in many respects allied to the saliva which is formed by the salivary glands.

In regard to the different forms of the digestive apparatus it may be presumed that the reader will not feel any great difficulty in understanding the very condensed description which has been given. The uses for which the different parts are required will appear as we proceed to discuss the changes which the food undergoes during the process of "digestion."

Food.—With the "Handbook on the Chemistry of the Farm" * before him, the writer feels that he is relieved from the necessity of entering into the subject of the constituents of food—further, at least, than is required to explain the relation of the different kinds of aliment to the tissues of the animal body.

To supply the loss of structure which is an inevitable consequence of motion and oxidation, animals require a certain quantity of albuminoids, fats, carbo-hydrates, and mineral matters. A peculiar class of compounds known to the chemist as "amides" are consumed by animals which feed on plants. But it is not necessary to say much about amides, because it is quite hopeless to expect the reader to grasp the subject. "Amides" are, in short, compounds which are formed when part of the hydrogen

* By R. Warington, F.C.S. Bradbury, Agnew, & Co.

of ammonia is substituted by a metal or an acid. They are, therefore, nitrogenous compounds, but they play no part in the repairing of nitrogenous tissues of animals, and can only be used as fuel for combustion. Their nitrogen is finally excreted as urea. As animals cannot support life without food which consists of the tissues of living beings—animals or plants—it follows that food must be derived from those two kingdoms.

Albuminoids, fats, and carbo-hydrates do not differ materially in the animal and plant world; and in selecting the kind of food with which an animal is to be supplied the origin of the aliment is of less moment than the habits of the animal to be fed. A dog can learn to live on vegetable albumen, fat, and starch: the animal's instincts, however, would lead it to select animal flesh and fat. In the same way a horse could be sustained on animal food, but the digestive organs are better fitted for the reception of vegetable aliment.

Beside the solid constituents of food which are required to compensate the waste of the tissue, a large quantity of fluid is an essential addition to the food. Something like four-fifths of the animal body are made up of water. Even after deducting the contents of the stomach and intestines the proportion is above three-fifths; and this ratio is kept up by the amount of water which exists in food, even dry food, and by the actual drinking of the fluid to which the animal is urged under the influence of thirst.

On the important matter of food in relation to the constituents of the animal body the reader is advised to turn to the "Chemistry of the Farm" (chapters vi. to ix. inclusive) before proceeding to follow the present writer in the attempt to describe the changes which food undergoes in various parts of the digestive system.

Digestion in the Mouth.—Animals have various ways of seizing their food in order to get it into the mouth, where it will be brought under the action of the teeth and cut or ground into sufficiently small portions.

The dog grasps its food with the fore paws and tears off a portion, which is swallowed after very slight mastication.

Horses use their lips to grasp the herbage or collect the corn or other food into a mass, which is then seized between the nippers, and by the aid of the tongue carried into the mouth and brought under the action of the molar teeth.

The ox uses its tongue to bring the food into a convenient position for cutting it off by the incisor teeth with their chisel-like edges; and the sheep employs the divided upper lip for the same purpose.

The pig uses its snout to root up favourite morsels out of the ground, or grasps it at once between its jaws, making meanwhile a characteristic noise.

In the cavity of the mouth the food is submitted to the process of cutting up or grinding (mastication), and mixing with the fluids of the mouth, chiefly saliva (insalivation). Mastication is a purely mechanical process, which is conducted by the agency of the muscles attached to the jaws. Animals which feed on flesh do not chew the food long, but after a few sharp bites, which serve to cut the morsel into small pieces, it is conveyed into the stomach. Herb and grain feeders grind their food into a paste, and during this action the saliva secreted by the salivary glands, and the mucus from the numerous mucous glands in the mouth, is mixed with the mass, rendering it soft and putting it in a state to pass readily down the swallow into the stomach.

Insalivation.—Saliva is a clear fluid, of alkaline reaction, containing rather less than one per cent. of solid matter, consisting of certain forms of albuminous matters called mucin, albumin, globulin, and ptyalin, which is a diastatic ferment. Therefore, besides softening the food, saliva sets up fermentation, which results in the changing of starch into grape sugar while mastication is going on, as can be proved by the simple experiment of chewing a little starch, or even mixing it with saliva, and then applying the necessary tests, it will be found that the ordinary test for starch no longer reacts, while the sugar tests give characteristic results.

After the process of digestion in the mouth has been carried far enough, the mass of food is pressed back into the pharynx by the action of the tongue, aided by the muscles of the cheeks. From the pharynx it passes into the upper part of the œsophagus, and, being grasped by the muscular walls of that tube, is quickly carried into the stomach.

Digestion in the Stomach.—To understand the changes which take place when the mass of softened food reaches the stomach it must be borne in mind that no alteration has yet been effected in the albuminoids or fats, that a good deal of the starch still remains unchanged, and also that the whole mass is alkaline.

In the stomach the food comes in contact with the gastric juice, which is a perfectly clear fluid, acid in reaction, being, in fact, a solution of pepsin with hydrochloric acid and some salts.

The chief action of the gastric juice is on the albuminoids, which are in some way rendered soluble and capable of passing through moist membranes. In this state they are called peptones. The pepsin, which effects the changes, is neither increased nor diminished during the process.

When carbo-hydrates are being digested in the stomach lactic acid is formed.

Food remains in the stomach for some time; and in consequence of the constant churning motions of the organ, which are produced by the action of its muscular coat, it may be supposed that every portion of the mass of food is at different times brought in contact with the gastric fluids

Digestion in the Stomach in Ruminants.—What has been stated in regard to the changes of the food in the stomach refers to the single stomach of the horse or pig, or to the fourth sac of the stomach of the ruminant. In the rumen, reticulum, and omasum no chemical changes in the albuminoids occur, but the food in these sacs is submitted to a process somewhat allied to cooking; and consequently ruminants can appropriate a larger proportion of vegetable fibre than animals with single stomachs can.*

Rumination.—When enough food has been masticated and swallowed to fill the rumen, the animal rests for a time and ruminates. By the action of the muscular walls and strong muscular bands of the rumen portions of food

* See "Chemistry of the Farm," chapter vii. Bradbury, Agnew, & Co.

are forced into the œsophagus and carried into the mouth, where they are again and again masticated and mixed with saliva, which fluid is secreted in enormous quantities. The combined results of these processes are the continuance of fermentation, which converts starch into sugar, and the perfect breaking up and softening of the vegetable fibre.

When a portion of food has been re-masticated it is again swallowed, but its destination is not quite a matter of certainty. The general idea is that it passes into the reticulum and thence through the omasum into the fourth stomach. There is, however, some reason to believe that everything which passes down the œsophagus goes into the rumen, afterwards getting to the other stomachs. It is not, from a practical point of view, of much consequence which of the two views is the correct one. The food does, after a long time and repeated mastication, pass into the second, third, and ultimately into the fourth stomach, where it meets with the gastric juice, which converts the albuminoids into peptones, as before explained. The product of digestion in the stomach is chyme, which is the result of chemical actions to which the food is subjected while in that organ.

Digestion in the Intestine.—In the first intestine the food again meets with alkaline secretions. There are the secretion from the follicles of the mucous membrane, the pancreatic fluid, and the bile. Experiments in the laboratory lead to the conclusion that the pancreatic fluid contains at least three kinds of ferments, one of which acts as a diastatic ferment and converts any starch which still remains in the mass into sugar; another, which acts on albuminoids and changes them into peptones ; and a third, which emulsionises fats.

Bile acts to a great extent as an antiseptic, and probably also assists in the solution of the large mass of epithelial cells which are displaced from the little tufts (villi) of the small intestines. It also acts in a peculiar way on the mucous membrane, and renders it permeable to the fatty matters.

In the first intestine the preparation of the food may be said to be completed by the formation of chyle, in which all the nutritive parts of the aliment are contained.

Absorption of Chyle.—For the rest of its course through the intestine the food does not appear to suffer much change in its chemical composition. The principal thing remaining to be done is the removal of the nutritive parts from the mass of waste matters with which they are associated. This is effected by the small blood vessels of the mucous membrane (capillaries), which take up all the dissolved nutriment, and by the absorbents (lacteals), which take the milky fluid containing particles of fats in the form of an emulsion.

The fluids which are absorbed from the intestine take different directions, but it will be seen that they meet in a common centre at last. That portion which is taken up by the capillaries passes with the blood into the veins of the intestines, which converge to form the portal veins of the liver, and in passing through this organ the blood is freed from some of the effete matters which it has collected in circulating over the body. From the liver the blood containing the recently absorbed nutriment from the intestine is sent on to the right side of the heart.

Meanwhile the chyle which was taken up by the lacteals has been carried by them along the mesentery through the mesenteric glands, in which an important change in the vital properties of the fluid occurs, into a large duct (the thoracic duct), which conveys it to the veins which are near the right cavities of the heart; on entering which organ it may be presumed to mix with the fluid also conveyed thither, which was taken from the intestines by the capillary vessels. From the right side of the heart the blood, mingled with the fluids resulting from the digestion of the food, passes through the vessels of the lungs, gives up some of its carbonic acid, and receives oxygen, is converted into arterial blood, is then returned to the left side of the heart and pumped over the system to devote its newly acquired stock of nutritive material to the support of the tissues.

After the vessels of the intestine, aided by the lacteals, have taken up as much of the nutritive material of the food as they can obtain during its passage through the canal, a large mass of ingesta still remains, which will be ultimately expelled in the form of manure, to be used for the food of plants. In this way the animal restores to the plant a large portion of the albuminoids, fats, and carbo-hydrates which it received from it as aliment. The returned material is not quite of the same quality, indeed, as that which was received; on the contrary, it consists largely of the worn-out and half-burnt tissues of the animal body, along with unused parts of the food. The plant, however, is content to take these leavings of the animal organism, only asking that the supply of oxygen, carbon, and nitrogen and water shall be liberal, never concerning itself much about the form in which they are given.

To the farmer the subject of the relation which exists between animal excreta and the nutrition of plants is one of really vital importance, and in the summing up of the evidence at the end of this Handbook something is said in respect of the principles of feeding with the double object of supporting and increasing the animal structures and at the same time providing for the excretion of valuable manure. But the farmer must not forget that on these points the "Chemistry of the Farm"* and "Plant Life"* are books to be consulted, as they contain valuable information which he cannot afford to lose.

* Bradbury, Agnew, & Co.

CHAPTER III.

BLOOD IN CIRCULATION.

Blood contains Living and Dead Matter—Structure under the Microscope—Corpuscles, Red and White—Amount of Blood in the Body compared with the Bulk of the Animal—Work of the Blood in the Process of Nutrition—Coagulation—Apparatus of Circulation—Heart and Vessels—Scheme of the Greater and Lesser Circulation—Pulse—Rate of the Blood's Motion—Lymphatic System—Sources of Loss and Gain.

Blood is "thicker than water" we are told, and the statement is perfectly true, not only in a poetical but in a physical sense, as any one knows who has seen the fluid running from a wounded vessel in a living animal; but blood has something beyond its colour and consistency to be considered.

At all times the popular mind has accepted the maxim that "the blood is the life thereof," and although it would be difficult to prove that the blood is more essential to life than is the air we breathe, it is quite certain that the fluid is the carrier of living material to all parts of the body. On the other hand, it may be said with equal truth that it also carries dead material all over the body. Blood, in fact, contains matter in several states: there is that which a short time ago was living in some of the animal structures, but is now dead and effete; matter which is in an active state of vitality—bioplasm; and matter recently introduced from the digestive system, ready to play its part in living texture, but not yet alive. There is, in fact, circulating through the vessels of the animal body, the blood of yesterday, to-day, and to-morrow.

Under the microscope, blood is seen to consist of a crowd of yellow round or oval discs floating in a colourless fluid. It is calculated that in the small space of a cubic millimetre (about $\frac{1}{25}$ of an inch) more than 1,000,000 corpuscles exist, of these about one in four hundred is colourless.

When the movement of the blood in the vessels of a frog's foot is watched under the microscope the corpuscles are seen rushing rapidly in two directions: through one set of vessels (arteries) away from the heart, and through the other (veins) towards that organ. Blood contains dissolved albuminoids, carbo-hydrates, various salts, especially the chloride, phosphate, and carbonate of soda; and held in suspension in the fluid there are also the gases, oxygen, nitrogen, and carbonic acid.

All the tissues of the animal are more or less charged with blood; even when the conduits are so small that the blood-corpuscles cannot enter, the nutritive fluid (plasma) flows into them. It is estimated that the total bulk of the blood as compared with that of the body is as 1 to 18 in the Horse, 1 to 20 in the Ox, and 1 to 22 in the Sheep. The estimate can only give the minimum, as even after the most complete removal of blood from the body a large quantity will still remain in the tissues.

Office of the Blood in Nutrition.—It has been shown that the nutritive fluids which result from the digestion of food, are sent directly into the blood stream, and after passing through the vessels of the lungs are carried into the tissues. It must not, however, be supposed that the blood is no more than the medium which is to convey the elements of nutrition ready prepared, and let them take their proper position. The blood has, as we shall see, certain qualities and duties which entitle it to special consideration.

Coagulation.—Blood drawn from a living animal and left at rest for a short time coagulates, or assumes the solid form, and then separates into two parts, the clot and the serous fluid in which it floats. An inspection of the clot will show that it is made up of white fibres which certainly did not exist when the blood was flowing through the vessels, and corpuscles, most of them red in colour.

No explanation of the use to the animal of the power of the blood to coagulate can be offered. It never occurs in the blood vessels under healthy conditions, and when caused by disease it is always a serious thing. Blood, when effused into any of the tissues or cavities, coagulates, but the process is never beneficial, and often very injurious. The older physiologists believed that coagulation was a vital act, a proof given by the blood of its own powers of life; the modern physiologist demonstrates in his test-tube that it is a chemical act, due to the union of two albuminoids of the blood (fibrino-plastin and fibrinogen), which are made to combine by the action of a ferment set free from the colourless blood-cells when the blood is removed from the vessels.

Coagulation can be made to occur in the vessels of the living animal by injecting into them blood in which the ferment is set free by previously breaking up the colourless cells; and the result is stoppage of the circulation.

From all we can learn of the circumstances under which coagulation occurs we cannot doubt that its occurrence is the reverse of beneficial to the living organism. What then, it may be asked, is the use of this peculiar property? Some outcome of it must be known. To which we may reply that it may be taken as a proof of the power of the blood to organise—an illustration of its activity even when removed from contact with living structure. The idea is not in accord with the strictly chemical view of the blood's properties and functions, but it may stand in place of a more scientific notion to be advanced perhaps in the future; and while in this unphilosophical vein, the writer may as well venture the statement that a good deal in the way of organising goes on in the blood which has not yet been clearly made out; that, in fact, the fluid not only contains all the constituents of the organisms, but is always engaged in the work of making them perfect before they are put in their right places.

Apparatus of Circulation.—The first idea which we get of circulation in simple forms of life, is the passing of the fluid in which the organism lives through its thin cell walls, carrying nutriment with it, and the after passing out of the fluid with the waste products of the body. Then we come to a simple piece of machinery in more advanced organisms, consisting of a single pulsating vessel, by which the fluid representing the blood is distributed. Next we find the simple heart, or contractile sac of the mollusc; then the double organ of the fish, and at length the complex muscular structure, with its separate cavities, valves, and vessels—the heart of the warm-blooded animal.

The Heart and its Vessels.—No clear idea can be formed of the structure of the heart without looking at the organ both inside and out; and the reader may be assured that it is easy and quite worth while to make the examination. First it will be seen that there are two sets of cavities on each side the heart: two above (auricles), which have rather thin walls, and two below, which are bounded by very thick walls, especially the left one. These cavities are the ventricles, and on looking into them from the upper cavities it will be observed that the communications are guarded by valves which are evidently meant to prevent the blood from the lower cavities getting into the upper ones.

From the lower cavities of the heart large yellow elastic tubes with thick walls (arteries) pass off to carry the blood away. Into the upper cavities enter thinner vessels (veins), which are the channels through which the blood gets back to the heart after it has gone over the system. Arteries and veins are in different degrees both elastic and contractile, the first named vessels possessing these properties in the highest degree. Arteries go *to* the tissues, dividing as they go into many branches, which of course get smaller until at last they lose themselves in hair-like tubes (capillaries). Then from the capillary tubes the vessels (veins), instead of dividing, begin to join themselves together, and they proceed towards the heart, still uniting, until they form a very few principal veins which pour the blood brought back from the tissues into the upper cavities of the heart, whence it passes into the ventricles.

Scheme of the Circulation.—A short account of the course which the blood takes from the heart and back again will be interesting to the reader, and is besides necessary to enable him to understand the work which the several parts of the circulatory system have to do. Any point will answer to start from, because we have to get back to it again, but it is usual to begin with the blood in the right and left auricles, which we may suppose to contract together and push the blood which they contain into the lower cavities, the ventricles. As soon as the auricles cease to contract, the ventricles begin and force their contents into the large arteries which proceed from them; the valves between the auricles and ventricles are closed during the contraction of the cavities, and consequently the blood cannot get back into the auricles. At this point we are to follow the blood along two different roads, which we can do in thought, but not in words, and must therefore describe the two journeys (both going on at the same time) separately. First, let us remember that the blood in the right side of the heart, or the right heart, as it is called, is impure, and has to go to the lungs to get oxygen and give up carbonic acid, and be set in order generally, while the blood in the left heart is good blood ready to be pumped over the system. Take the journey through the lungs, the lesser circulation, to begin with.

When the two ventricles contract, the blood from the right one is driven into the large artery which goes to the lungs, dividing into numerous branches, and lastly ending in the fine capillaries which form a network over the air cells. The blood passing through this network of vessels is only separated from the air in the lungs by the thin walls of the capillaries and those of the air cells, and through these membranes the gases of the blood pass into the air cells and the purer air from the cells passes into the blood. Continuing its course through the lungs, the blood enters the small veins, which gradually unite together, and at last end in the left auricle by four openings. From the left auricle the renovated blood passes on its way to the left ventricle.

At the same time that the **lesser circulation** is going on through the lungs from the right side of the heart back to the left, the **greater circulation** is also going on from the left side of the heart over the system back to the right side. As the right ventricle contracts and sends the blood into the lungs, the left ventricle contracts and sends the blood into the large artery (aorta), which soon divides into two great branches, one going to the neck and fore parts of the body, and the other to the hind parts, conducting the blood to all the organs and structures for their support, and to enable them to do the work which is required of them.

Through the capillaries of the system the blood passes, but in the act of passing something happens to the fluid quite different from what occurs in the capillaries of the lungs. In the lungs, as we have seen, the blood gets oxygen and gives up carbonic acid. In the capillaries of the system the oxygen of the blood attacks the carbohydrates, and burns them up, causing the usual result of burning—heat, which is stored up in the tissues. The products of this burning—carbonic acid and water—get into the blood in place of the oxygen, and the fluid becomes so much the worse for the change and has to try hard, during its course back to the heart, to get rid of some of these impurities and also of other useless products (extractive matters) which it has to carry away from various structures.

In the passage through the veins of the system which join together as they proceed to the heart, until they are mainly resolved into two very large vessels, the blood goes through the kidneys, the liver, and the spleen or milt, and in all of these organs important changes occur, tending to remove from the fluid the effete matters and supply new and useful substances instead.

In getting rid of the gaseous impurities, the skin affords material aid, but it is not until the blood goes through into the right side of the heart by the large veins and reaches the lungs that the great changes between the oxygen in the air cells and the carbonic acid in the blood takes place.

Now, if the reader will go over this description of the circulation until he can follow it easily, and then shut the book—and his eyes too, if he likes—he will, if his imagination is fairly active, see the whole process going on at once; and unless he can see it with his mental eye he may be certain that he has not grasped the facts as they have been stated.

The Pulse.—In the living animal the blood-vessels are always filled with blood, and so are the upper and lower cavities of the heart alternately, and when the ventricles contract they send a mass of blood into already full vessels, with a jerk which imparts a shock to the whole of the fluid, and causes the elastic arteries to yield to the pressure. Further, the heart contracts at regular intervals, or ryhthmically, as it as called, without ceasing during life; and each rythmical shock, being followed by a very short interval of rest, gives rise to the Pulse, which may be seen and felt in all the arteries excepting the very smallest of them. The number of shocks which the heart gives to the mass of blood every minute varies in different animals. In the horse the beats of the heart and arteries amount to about 36 in the minute; in the ox, 50 to 55, and in the sheep about 75. In man the standard may be fixed at 70, but in all animals variations in the number of the beats of the pulse occur even in good health, according to age and other conditions.

Rapidity of Circulation.—The blood goes all over the body from the heart and back again in a very short time, much shorter than any one would have supposed before the point was settled by experiment. The rate of movement, it may be remarked, does not depend on the size of the animal. Nor is it in proportion to the beats of the pulse. In the dog, with a pulse of 100 in the minute, the whole round of circulation is performed in 10 seconds, while in the horse, with a pulse of 36 in the minute, it occupies 20 seconds. The quickness of the movements of the blood may perhaps be better understood by reference to observations which have been made on different vessels in living animals; for example, it is estimated that the blood moves in the carotid artery of the horse, during the contraction of the ventricles, at the rate of 20 to 28 inches in one second, or at an average speed of 40 yards in a minute—not quite the speed of an express train, which easily gets over 1,760 yards in the same time; but then the blood is not wanted to race against time, but is often bound to loiter on the way, its chief duty being to do its work well rather than quickly.

Lymphatic Vessels.—All the tissues of the body receive from the capillaries a supply of nutritive fluid which flows into them probably without cessation. They get, therefore, more than they want, and would suffer from the excess if there was not some way of getting rid of the, to them, useless matter, which is too valuable to be lost. At this stage of the process of nutrition the absorbent system begins its work. Numerous small vessels (lymphatics) arise in the tissues and take up the excess of nutriment which flows into them. The lymphatic vessels, after passing through many small glands, join together as veins do, and form larger tubes which enter the thoracic duct before referred to as the vessel which receives the chyle which the lacteals bring from the intestines. This duct enters the large veins and pours its contents into the blood going to the right side of the heart. In this way all the fluids absorbed from the tissues, as well as from the intestinal canal, get into the blood stream.

Sources of Loss and Gain.—How very valuable is the aid which the lymphatics afford may be judged from the fact that the blood gives up to the tissues and gets back again from the absorbents something like its own bulk every twenty-four hours. In fact there is a regular debtor and creditor account going on, and a balance is struck at intervals. The blood suffers loss by the work of Repairing tissues, by Secretion, and Excretion; it gains by Alimentation, also from the Lungs, the Liver, and largely from the Lymphatics; and when everything is properly balanced the organism is in that happy state which is described as "Physiological Equilibrium."

CHAPTER IV.

RESPIRATION.

What is meant by Breathing—Breathing by the Skin—Structure of the Lungs—Bronchial Tubes—Windpipe—The Chest—Ribs—Diaphragm—Muscles—How the Air enters the Lungs—Process of Expiration—Number of Respirations in a Minute in the Horse, Ox, Sheep, and Pig—Amount of Air which remains in the Lungs—Circulation in its Relation to Respiration—Lymph and Chyle Pass through the Lungs—Effects of Breathing on the Air, on the Blood, on the Tissues—Respiration, its Relation to Nutrition, and the Deposit of Flesh and Fat.

Respiration.—What has breathing to do with nutrition? More than appears at first sight. Breathing, as most people think, is taking air into the lungs and sending it out again; but we cannot really understand any of the actions which take place in the system of the higher animal until we stoop down a little and find out what goes on in lower organisms, for example, among the little creatures which form part of the marvels of Pond Life.

The most simple organisms breathe by simply letting the air into all their tissues, so that every molecule of living substance may have its share of oxygen, which unites with carbon and hydrogen, to form carbonic acid and water, and changes some of the nitrogenous tissues into urea, which has to be excreted with the water and carbonic acid by-and-by. Now we cannot suppose that in the higher organisms the act of breathing is less perfect than it is in the lower; and yet that is just what is constantly done by those who teach that breathing is a work which is only carried on by the lungs. This mistake cannot be made in regard to the lowest forms of animal life, because there are no lungs or other defined organs to lead us astray.

Breathing in the higher animal is carried on chiefly by the aid of the blood in circulation. The air in contact with the outside of the body assists a little in the work, but the skins of the animals of the farm are not adapted to take in air as the skins of insects are, and so it has to get into the lungs in order that the blood may have a constant supply to take to the tissues to enable them to breathe.

Respiration, to judge from the account which has been given, is a very simple affair, easy to understand. Indeed, we may come to believe that all the functions of life are simple and easily understood, if we can only get rid of the idea that all science is abstract and puzzling, and above ordinary comprehension—a totally wrong notion, much fostered by scientists, who will put their thoughts into dead words instead of living ones.

Respiratory Apparatus.—The organs which are concerned in breathing are the lungs—two elastic bags divided into numerous smaller bags (air cells) and the tubes which connect them with the outer air. In reptiles the lungs are actually bags on which the blood-vessels are distributed, and the air is taken into the bags by the act of swallowing it; and when a fresh supply is wanted by the animal the used-up air is ejected and more is taken in. The lungs of the higher animals, as the horse and ox, are elastic bags, which have an infinite number of little bags (air cells) inside them, and also of tubes (bronchial tubes), uniting together to form the windpipe (trachea), which passes up the neck to the mouth and nostrils, so as to open a free communication with the air outside the body.

Every one of the little air bags has on its outside a fine network of blood-vessels (capillaries), formed by the splitting up of the large artery which goes from the right side of the heart to the lungs. From these capillaries arise the veins which carry the blood out of the lungs to the left side of the heart after it has taken in a supply of fresh air.

Cavity of the Chest.—The lungs are suspended in the large cavity which is formed by the ribs on each side, the spine at the top, the breast bone (sternum) at the bottom, and the muscular partition (the diaphragm), which divides the chest from the abdomen, behind. Between the lungs hangs the heart, connected with them by its large vessels.

The cavity of the chest is lined by a fine smooth serous membrane (pleura), which is reflected over the lungs, so that during the movements which occur in breathing the two smooth surfaces glide easily over each other.

How the Air passes into and out of the Lungs.—Animals like the horse and ox do not swallow the air, as reptiles do ; in fact, it passes into the lungs without any effort on the part of the animal at all, as a simple result of atmospheric pressure. What really takes place is this : the muscles outside the walls of the chest contract and lift the ribs outwards and forwards. The diaphragm contracts and so becomes less convex towards the chest than it was before; by these means the size of the cavity is increased, and the air in the lungs has more room, and this means that the pressure is lessened, or would be lessened, but the air from the outside rushes down the windpipe until the pressure of air in the lung and outside the nostrils is equal. This is a purely physical act of the most simple kind, merely an illustration of the law of equal diffusion of gases—a proof of the truth of the doctrine poetically expressed in the line, "Nature abhors a vacuum."

As soon as the lungs are full the muscular contraction which caused the expansion of the chest ceases, and the walls of the cavity and the tissues of the lungs are left free to exercise their elasticity and return to their former condition. By this elastic action, chiefly, the air is forced out of the lungs, the process being aided by the contraction of the muscles of the walls of the abdomen. The exact extent and character of this action can be seen by watching the movements of the flanks of a horse while at rest in the stable.

Number of Respirations in a given period.—It takes some time to explain the act of breathing—taking air into the lungs and forcing it out again; but some of the animals of the farm perform the act very quickly, and the looker-on may be rather puzzled about the entrance of oxygen into the blood and the exit of carbonic acid from it into the air cells when he sees a sheep breathing at a rate varying from thirty to two hundred times in a minute. The rate in the other animals of the farm is not so great. The horse, for instance, breathes from eight to ten times, the ox from fifteen to twenty-five, and even up to fifty times, and the pig from fifteen to twenty-five times in a minute, but at this rate may be supposed to be too quick to give time for the exchange of gases, and quite certainly it is too quick for the purpose; but the fact is, the rate of the movements of the chest has nothing to do with that matter. The air which is actually breathed—that is, taken into the lungs and forced out again—is only a small part of the amount of air which is always retained in the lungs and cannot be expelled. Even after a most vigorous effort at expiration there remains in the lungs "residual air," more than three times the amount of the air which is breathed a certain number of times every minute.

It will by this time perhaps have occurred to the reader that the interchange of gases in the lungs takes place between the blood, and the air, which is stationary, in the lungs, and is not immediately effected by the air which is breathed.

It is so important to understand what really occurs in the lungs during respiration that we must state the facts once more in new words. When the chest expands a small amount of outside air, not much above an eighth part of the amount which the lungs ordinarily contain, passes into the lung tubes and begins to mix with air already there. The air, which is directly forced out again to complete the act of breathing, is partly the air which was just before taken in, mixed with the impure air which it met with on its entrance.

So far the respiratory apparatus, including the lungs and the windpipe, appears to be useful to the organism chiefly as receptacles for air and blood. We may now ask what happens during the double process—the circulation of the blood through the lungs, and the entrance and exit of the atmosphere. We have already seen that the blood receives a constant supply of new material from the intestinal canals through the lacteals and the capillaries, which take up the chyle and the dissolved constituents of the food; and also from the lymphatic vessels, which return to the blood the excess of fluid which the tissues are unable to use. It has also been pointed out that the whole of the products of digestion and lymphatic absorption are carried into the blood stream which is going to the right heart by the veins. These products must therefore pass through the lungs before they circulate over the system. It is, indeed, rather a curious fact that the nutritive fluids derived from the food during digestion should go into the *veins* and be mixed with *impure* blood on its way to the lungs to be renovated, instead of going directly into the arteries to mix with the blood which is ready to be used for the repair of the wasted tissues.

The fact that lymph and chyle are both taken through the capillary system of the lungs, before they are used for the support of the organism, suggests that there is something to be done with them, but it must be admitted that the changes which occur in the lungs do not offer a satisfactory answer to the question what is done.

Effects of Breathing on the Air.—The atmosphere which is taken into the lungs several times every minute consists chiefly of oxygen and nitrogen, with certain impurities, which vary according to the locality in which the animal lives. When the air returns from the lungs it is found to have lost about a fourth part of its oxygen, and to have a large amount of carbonic acid mixed with it. It is also charged with moisture, and its temperature is raised to nearly that of the animal body. A certain quantity of organic impurities is mixed with the expired air, as proved by the peculiar odour which it possesses.

Effects of Respiration on the Blood in the Lungs.— When the blood from the right heart enters the lungs it is dark in colour, contains an excess of carbonic acid and moisture, and is deficient in oxygen: when it leaves the lungs to return to the left heart to be sent all over the body, it is bright red in colour, is rich in oxygen, and has given up much of the carbonic acid, and other impurities which it contained when it entered the lungs. And now comes the further process of breathing which is usually left out of the question.

Effects of Respiration on the Tissues.—At one time the lungs were looked upon as the centres of combustion, the furnaces in which heat was produced to keep up the temperature of the system. This view was shown to be wrong by chemical experiments which were not open to doubt, and it is now well known that combustion, so far from being confined to the lungs, occurs, to a much greater extent, in all organs and tissues of the body; and we may even admit with Küss that the lungs are only a part, and not the most important part, of the respiratory system. When the blood leaves the lungs the important part of the respiratory process begins; the fluid charged with oxygen enters every portion of the tissues. We come back now to the simple idea of breathing with which we started at the beginning of this chapter. The tissues of the highest animal are now seen to be breathing just in the same way as the tissues of the amœba breathe; oxidation goes on in the living substance—bioplasm—carbonic acid, water, and urea are formed; and—most important of all—heat and force are evolved and stored up for future use by the organism.

Besides imparting oxygen to burn up tissue, with the grand results, heat and force, the blood at the same time does two other essential things; it yields up the nutriment which it received from the digestive system, and also from the lymphatics after having finally fitted it to form living matter; and, further, it receives from the tissues the waste products of oxidation and takes them away to be excreted by various organs through which it passes on the way back to the lungs to dispose of carbonic acid and get a new supply of oxygen.

The whole story of respiration may be shortly told. Breathing is chiefly done in the blood and in the elementary tissues of the body, and is an absolutely necessary part of nutrition. The blood is the fluid which carries the air into the tissues to enable them to breathe. The central breathing organs, the lungs, play, after all, a subordinate part. They only take in fresh air to supply the blood and throw off the impure air containing gaseous and other products of oxidation of the tissues.

Respiration in relation to the Process of Nutrition.—At this stage of our subject we may just touch a point of practice, which is again brought forward in the concluding part of this Handbook. It has been distinctly stated that respiration is part of the process of nutrition, but we have only succeeded in showing that when the air gets into the tissues it burns them up. Well, it is just this destructive action which is the most important thing in nutrition; the tissues, which are burnt, are soon replaced, and the result of their burning is heat, which is an important factor in nutrition. When respiration is imperfectly performed either from the breathing of bad air, or from some defect in the machinery, nutrition goes on very slowly; the worn-out structures are not burnt up and replaced by new matter; effete materials accumulate in the blood, and the whole organism goes wrong. Give the animal plenty of fresh air, and it becomes "meat and drink and clothes" to him, imparting life, and warmth, and energy to the remotest parts of his body.

Respiratory capacity, meaning the power of the lungs to take in air, is a matter which the practical stock-owner has to consider very carefully in selecting animals for their different positions on the farm. A capacious chest to give room for large lungs, full power of breathing muscles, good open nostrils for the free entrance of air, and full opportunity for the exercise of the apparatus, are the conditions of active vitality, energy, and robust health—in fine, are desirable things when robust health in the live stock of the farm is the object of the breeder and feeder. "As it always is," the reader remarks. "As it generally is *not*," the writer replies.

Look for one moment at what great breathing capacity, muscular force, and robust health mean to the animal. First, they mean the introduction into the blood of plenty of oxygen, which will certainly keep the animal's energy and heat up to the highest standard. How? By burning up its fat. Next, force means active, strong, condensed muscles—in plain terms, what the trainer calls "good hard meat." Lastly, the conditions of robust health mean the development of flesh in those parts of the body which are least esteemed by the butcher—and his customers: the absence of superfluous fat and the growth of those organs of the body which come under the contemptuous title of offal. Is this what the stock-owner aims at in the cultivation of flocks and herds? If a reply is really required it will be found farther on.

CHAPTER V.

THE NUTRITIVE PROCESS COMPLETED.

Results of Nutrition—The Animal Body formed—Bone—Flesh—Fat—The Skeleton—Head—Neck—Trunk—Extremities—Spinal Column—Ribs—Cavities Formed by Bone—Cranium—Orbits—Mouth—Nasal Chambers—Chest—Pelvis—Soft Structures—Flesh and Fat—Contractility a Property of Living Matter—Locomotion—Fatty Tissue, uses in Animal Economy—Skin Investing the Whole of the Body—Functions—Absorption of Gases—Secretion and Excretion of Effete Substances—Relation of Skin to the Kidneys.

Form.—Looking at a well-formed healthy specimen of one of the Animals of the Farm, we may to some extent realise the importance of the nutritive functions which we have been occupied in discussing. Clearly the horse, ox, sheep, or pig, at its full growth must have required some building up. And for the present our attention is diverted from the machinery which has to do the work of building the Body, to the Body which is built.

The judge of form and quality in farm-stock is not content with a general view. To satisfy himself in the matter of points he must, in his mind, divide the body into parts—as head, neck, trunk, and extremities. And even with the slight knowledge of anatomy which every one has, he feels compelled to go a little further, and look beneath the surface to the bones, flesh, fat, and organs.

To enter upon a consideration of the Law of Form is not one of the objects which we have in view, but we may allude in passing to the power which the breeder of stock possesses—and, indeed, has exercised—to modify the form of the animal body by the selection of parents which exhibit the special characters of his artificial standard of perfection. The breeder has one type of Form for the Hunter as distinct from the Draft-horse, and another quite different type for animals which are intended for butcher's meat. Most of the qualities which he demands in one animal would be objectionable in the others, and in the pursuit of his object he has, by careful attention to details, succeeded in showing how far it is possible to modify form and character by a system of artificial selection.

Structures of which the Body is made up.—If the question were put, What is the outcome of the nutritive functions, including digestion, circulation, respiration, secretion, and absorption? we might fairly reply, The Development and Growth of the body. In fact, to put the case quite plainly, as the grower of stock would state it, the use of all the complex processes of nutrition is to build up the animal, horse, ox, sheep, or pig, ready for the purpose for which it is wanted. This is the end according to the popular view of the matter; but it seems that it cannot be reached otherwise than by the means of numerous chemical and physical actions, which are mostly carried on secretly in the interior of the organism in such a way that it is very difficult to observe them.

If mystery and complication are necessary we are perforce content to fall in with the arrangement. But does it not often occur to us that if the result could be gained in a more obvious and simple manner we should be quite ready to welcome the new system. This sort of reasoning, when put into words, seems rather too absurd to be seriously intended ; but if we choose to submit our views and sentiments in regard to the animals, which we keep for our pleasure or our profit, to fair criticism, the result will be very much as we have expressed it. What amount of thought, for instance, does the breeder bestow on the process of development of the embryonic tissues from the segmentation of a single minute mass of living substance in the mature ovum? Does the grazier care by what kinds of ferments the food with which he supplies his fattening stock will be rendered soluble and ultimately be fitted to form part of the living tissues? It is sufficient for him to know that a certain quantity of food per day is necessary to get his stock fit for the market. The unseen changes by which the result is secured are not merely uninteresting to him ; they simply never cross his mind at all. And so in regard to every function of animal life. We have a sort of conviction that animals must eat and drink and breathe; we know that their hearts beat, and we believe that the blood circulates through the vessels; but very seldom does it occur to ask the why and wherefore, partly, perhaps, because we do not expect to get an answer which would make the matter any clearer than it was before, but chiefly from the lack of that noble curiosity which is the main motive of all inquiry.

In the preceding pages we have tried, by giving a short and simple description of the functions of Organic Life to rouse enough of curiosity to lead to the question, What does it all mean? The answer to the question may not be quite satisfactory, and the reader may in the end be left wondering. If so, one of the objects of the Handbooks of the Farm Series will be gained.

After this gossip, which has not led to anything very definite, we may proceed to the consideration of the parts of the animal frame, which it has been the object of the nutritive process to construct.

Bone.—As the basis and framework of the animal, bone requires some notice. It may be defined as a hard, white, comparatively insensitive structure, composed of a large proportion of mineral matter, chiefly phosphate of lime, with about one-third of animal matter, which gives the degree of elasticity which is required to counterbalance the tendency to fracture.

The head comes naturally first in order, and without noting its shape particularly, although there is much to be noted in that, the observer may look into the various cavities. At the upper part of the skull are the cranial bones, bounding the cavity in which the brain is lodged, with the beginning of the spinal cord (medulla), which passes out of the cranium by a large hole where the head joins the neck, and runs the whole length of the chain of bones extending from the head to the tail. Below the cranial cavity are seen the orbits for the reception of the eyes. Farther back, the hard temporal bones which are occupied by the wonderful structures of the internal ear. The cavity of the mouth, with the movable lower jaws, and the entrance to the nasal chambers, attract their share of attention.

After the head the bones of the spine may be examined; several distinct types of form will be seen in the bones of the neck, back, loins, croup, and tail. All these regions of the skeleton are interesting to the breeder of stock; and he has, almost without knowing it, to keep in his mind a standard form for each class of animal which it is his object to bring to the highest point of perfection.

If a skeleton of a horse is under inspection the eye of the judge is satisfied with lines of neck and back which would startle him if they appeared in the bony framework of an ox or sheep. In the top line of the horse he looks for curves which suggest graceful and elastic action of head, neck and body. In the animals which are bred for the making of meat the straight line from the crest of the head to the last bone of the croup is the only "line of beauty" in the eye of the butcher.

From each side of the bones of the region of the back the ribs branch off, forming the sides of the cavity of the chest, and uniting at the base, either directly or indirectly, with the breast-bone (sternum). Again the mind of the breeder is directed to arrangement of parts. The cavity of the chest is an all-important point in conformation. If the animal is to be used for work in which power of wind and strength of limb are wanted, a deep chest, meaning thereby long ribs, is to be desired, to afford room for capacious lungs. Moderately flat sides rather than round are also to be commended, as the form of body offering the least surface for the air to resist. But in the ox, sheep and pig, roundness of form is a good point in the skeleton, too much depth of breathing space is not wanted, and a round barrel gives room for flesh and fat over the ribs.

Next to the back and ribs the bones of the loins come in for a share of criticism; the mechanism will be looked at favourably or the reverse according to the position of the animal. It will naturally be allowed that length of loin-bones and great breadth of the spines which spread out laterally from each bone are valuable points in animals which are used for food, because breadth and length of loins mean so much space for meat of the quality most esteemed in the market.

Attached to the mass of bone which extends from the loins to the first bone of the tail (sacrum or croup), the broad, irregularly shaped bones which form the hips are seen. The first use of these structures is to form the boundaries of the cavity of the pelvis which is occupied by part of the urinary and genital organs; next they form joints with the bones of the hind limbs, uniting them to the trunk; and lastly, they offer a large surface for the deposit of meat on food animals, or for the accommodation of strong muscles which give power to the hind quarters. This region does not present any marked differences of type in animals which are used for work and those which are fed for the butcher, excepting that in the latter the breeder does not encourage, rather aims to get rid of, those large, rough projections which give firm points of attachment to the muscles of the hips, enabling them to act with advantage in work requiring strength or speed.

The parts of the skeleton which have been described, the head, neck, and trunk, are in their natural position raised above the ground by four supporting pillars, the fore and hind extremities, which are also the agents of locomotion.

The fore extremities consist of the shoulder-blades, the bones of the arm, the forearm, the bones of the knee-joints, which are represented by the wrists of man, the shank bones (with the splint bones in the horse) the pasterns, the coronet bones, and the bones of the foot.

In the hind extremity the bones are the thigh bones, which form a joint with the hip on each side; the bones of the legs, which joint the thigh bone at the stifle joint with its loosely attached bone in front (the knee-cap of man); then the bones of the hock (the ankle of man), and the rest of the bones down to the foot as in the fore limb.

Between the fore and hind extremities there are peculiarities of arrangement which are worth notice. First, in all the animals of the farm the fore limbs are united to the trunk by muscles, and not as the hind extremities are by the formation of a true joint. Then the angles which are formed by the junction of the several bones are quite different in the two cases. The shoulder-blade forms an angle with the bone of the arm; and that bone, with the bones of the fore arm at the elbow-joint. Below the elbow the bone forms a nearly straight line to the fetlock.

In the horse, the position of the shoulder-blade and arm bones is a matter of the utmost importance to the animal's form and action, making, indeed, all the difference between a good shoulder and a bad one. In food animals the angles formed are points of secondary importance, but on the other hand it is desirable to have well developed shoulders, and small, compact, and short limbs below the elbows, as they are chiefly wanted to support the trunk, locomotion not being of consequence; and these parts do not possess any value as food.

The above remarks apply equally to the bones which form the hind limbs. In the horse the propelling power is regulated by the angles which the bones form, but propelling power is not of moment in the other animals of the farm, and fineness and small size of the bones are of more value than perfection of mechanism.

Joints.—All parts of the bony framework of the animal body are arranged to move, sometimes freely, and in other cases only to a very limited degree; always, however, to an extent sufficient for the requirements of the part. Anatomists have shown great ingenuity in classifying, and especially in naming, the various kinds of joints of which examples are afforded in the skeleton, but it is not necessary to enter into details; it may, however, be explained that the principal joints are hinge-like, ball and socket (rotatory), or gliding in their movement; and in all cases where these free movements are possessed, the surfaces of the bones are rendered smooth by a covering of cartilage (gristle); and the cavity of the joint is kept moist by "joint-oil" (synovia), an albuminous fluid which is secreted from a vascular fringe which is attached to the outer edge or circumference of the joint surface.

To keep the bones in their proper position strong fibrous bands (ligaments) are attached to them, and in most cases the whole of the joint is enclosed in a fine layer of interlaced fibres, forming the capsular ligament.

From the little which has been said in regard to the mechanism of the skeleton it is apparent that even the unscientific looker on may gather from the dry bones something of the characters and habits of the animals to which they belonged. An accomplished naturalist would gather much more. Mr. Huxley could tell a good deal of the life history of a beast or bird or fish, if we only gave him a single bone of either to read from.

Soft Tissues.—For the filling up of the hollows and irregularities in the bony frame of the animal, flesh and fat are employed. In regard to these tissues we are taught that they are good for food of man, and without much compunction we accept the idea, and devote the flesh and fat of most of the animals of the farm to the purpose of our own support accordingly.

Even were the writer anxious to oppose the view that all things are meant for man, which he is not, the effort would be useless, as such efforts, even when made by consistent and well-meaning people, always have been; but he may be permitted, from the point of view of a physiologist, to suggest that the flesh and fat are of some use to the animals of which they form a part as well as to us who eat them. Indeed, the fact will be evident as we go on.

Flesh.—Muscular Structure.—By using the word **muscle** instead of flesh we take the first step in the explanation of the uses to the animal of this structure. Everyone knows that muscle has a power of contraction; but everyone does not quite realise the fact that flesh or meat is really muscular tissue, a collection of fibres joined together to form a muscle, which is in fact an organ situated in a particular part of the body for the purpose of moving that part. Any ordinary joint of meat contains portions of several muscles united loosely by connective tissue; and an anatomist who helps a friend to a slice out of a leg of mutton could give him at the same time the names, forms, attachments, and uses of the muscles through which he has cut.

Muscles possess the power of contracting and thus pulling nearer together the parts to which they are attached. A muscle which arises at the back of the leg near the elbow in the horse, for instance, is attached to the bone of the foot by the long tendon or back sinew.

When this muscle contracts, the fore foot is pulled or lifted up. Another muscle in front of the leg pulls the limb in a forward direction, and when similar actions go on in the fore and hind limbs at the same time, or rather alternately, the body is moved forward at a rate proportioned to the rapidity of the contraction.

Muscles are generally arranged in pairs, and by their constant, steady contraction (tonicity) the symmetry of the body is preserved. The distortion which results from the loss of tonicity in one set of muscles is well seen in paralysis of the muscles of the side of the face. In this disease the features are drawn to the healthy side, because the balance of power which kept them in the centre of two sets of muscles, pulling in opposite directions, is lost.

Of the cause of muscular contraction many explanations have been offered. It is sufficient to say that it is a property of living matter (bioplasm) and is not confined to one special form of structure. In the lowest forms of life in the animal and plant worlds, we see under the microscope the property in full exercise in little masses which possess no fibres or other structures which can be seen; and we know that the muscles of the highest animals are made up of minute fibres or tubes which are filled with bioplasm, and their peculiar power of contraction is only a manifestation of their vitality.

Varieties of Muscle.—Muscular structure is found in the organism in two quite distinct forms, each of which has special duties to perform. Externally we observe the great masses of muscle which move the body and limbs, as the animal may desire, or be forced, to move. This structure is red in colour, forming what we call the lean of meat; its fibrous character is seen by the unaided eye, especially in cooked meat. When the muscle-fibres are carefully examined it will be seen that they are marked by lines which run transversely and very close together. The appearance gives rise to the term **striated muscle**, and nearly all the muscles so marked may be moved under the direction of the animal's Will.

Another form of muscular structure exists in the interior of the organism, forming one of the coats of the hollow organs: the blood vessels, especially the smaller arteries; the digestive canal, the urinary bladder, and the uterus, for example. This variety of muscle is white in colour and has no transverse lines, and is therefore called **non-striated** or **smooth** muscle; its fibres are minute flattened bands, composed of cells which are elongated and joined together by their edges.

Smooth muscle has the power of contraction like striated muscle; but the power is not exerted suddenly as the animal may determine, it is always being exercised in the movements of the various organs in which motions are carried on without the interference of the animal's will, and generally without its consciousness. The action is therefore called involuntary. It may be well to note here that the heart is one of the hollow organs which acts without the stimulus of the animal's will; but the muscular structure of the heart is red in colour, and is striated, not smooth. The heart in fact is an exceptional instance of red striated muscle contracting regularly and constantly without being in any degree under the control of the animal's will.

Irritability.—Contraction of muscle is the effect of the excitation of the irritability of the structure, a property which it has independently of the nerves which are supplied to it, as shown by the action of a stimulus on a muscle when quite disconnected from the nerves.

Stimuli may act on muscle directly or through the medium of nerves. In the case of the muscles of the internal organs generally, the stimulus is produced by the contact of some substances which are proper to the organ; for example, the blood is the natural stimulus of the irritability of the heart; the food stimulates the muscles of the stomach and intestines. It appears from observations which have been made, that the effect of a stimulus on the irritability of muscle is not absolutely immediate; but that a period which can be measured intervenes between the application of the stimulus and the beginning of contraction; this is called the period of latent contraction. How extremely small the period of latent contraction is in some cases, will be evident to one who observes the movements—not of the fleetest racehorse, but of the wings of insects, or even of the creatures themselves.

Mr. Francis Darwin remarks that a fly living in the same room with an active-minded boy owes its life to the rapidity with which it appreciates the mere shadow of the boy's approaching hand; and he refers to the sudden action of the fly in these circumstances as an illustration of the "*exploding power*" of irritable tissue.

It has been calculated that the wings of insects strike the air many *thousand* times in a second. No words can convey an idea of the time required for each separate effort of the muscles by which the wings are moved. But, in regard to less rapid motion, it is known that muscular contractions take place in the two-hundredth part of a second for several minutes, as in the case of the limbs of a dog at full speed; or at the more reasonable rate of fifty in a second, as in the movements of the tongue during rapid speech.

Muscular Energy.—The force with which muscles contract may be best understood by reference to the amount of shortening which occurs when the power is allowed full play by cutting away the structure at the point of insertion. A portion of smooth muscle will contract to one-third of its ordinary length; striated muscle will contract to one-fifth of its length. A muscle, that is to say, ten inches long, can shorten itself two inches, provided that no resistance be offered to the exercise of its contractile power.

A contracted muscle is usually suggestive of density and hardness. When an athlete wishes to display the muscular power of his arm, he flexes it forcibly and causes his biceps to rise up, a hard, bulging mass. The odd thing about the act of contraction, however, is, that when a muscle is fully contracted, it becomes a globular mass of soft material; and if the athlete will flex his arm without any effort, he will be disgusted with the flabbiness of his famous biceps. It is only when the act of contraction is resisted by weight, or by any opposing force, that the muscle becomes hard.

Uniformity in Muscular Action.—The terms "symmetry" and "harmony" of movement are used by physiologists to express the effects of muscular contraction in moving the body and limbs. In the various positions of standing, lying down, walking, and running, and in the motions of the eyeball, and of certain parts of the organism, while other parts are at rest, this peculiar property of muscle is shown ; and it is especially worthy of remark that it is exhibited in its most perfect form when muscles of different sets are acting at the same time on the two sides of the body.

Harmony of motion is not, it may be thought, a subject of much consequence to the breeder of farm stock ; and in respect of the ox, sheep, and pig—the latter particularly—the objection may be allowed with some limitation. But to the breeder of horses the matter is one of profound interest. Action—in the walk, trot, canter, and gallop—is everything; although it does not perhaps occur to the judge in the horse-ring when he criticises the paces of the animals before him, that he is looking for the horse whose muscles are acting in the most harmonious manner; it is, nevertheless, the fact, that his decision will be materially influenced by the degree to which this curious function is exhibited ; and it can hardly be questioned that the more he knows of the structures of the animal body and their uses, the better his judgment will be.

To the practical breeder it will occur that his chief object should be to cultivate this quality of symmetry of action ; and his experience teaches him that this can be done by the selection of stock animals which show it in the highest degree, not forgetting at the same time that it is capable of improvement by training.

Sources of Muscular Power.—Scientists have decided that heat is changed into force ; and in the tissues of the organism heat is due to oxidation.

Combustion occurs not only in the blood, which circulates freely through muscles as indispensable to their life and activity, but also in the nutritive fluid which is always flowing into them from the blood-vessels and in the elements of the muscle. Heat is produced at the expense of the structure of the parts which are converted into carbonic acid and water. That the nitrogenous constituents of muscle are oxidised as well as the non-nitrogenous, appears from the fact of the increase of urea, which is eliminated after severe exertion; but non-nitrogenous compounds are, of course, burnt up to the greatest extent.

Non-nitrogenous food is capable of supplying the waste of muscle to a great extent and for a certain time; but numerous experiments have shown that albuminoids are absolutely essential for the perfect support of the structure under exertion; and it is only under such conditions that the full development of its force is possible.

Rigor Mortis.—Muscle undergoes a singular change after the death of the animal, known as "death stiffening" or "rigor mortis." It seems to depend on the coagulation of the plasma of the muscle, and occurs usually in six or seven hours after death, and lasts for some twenty-four to thirty hours. The change may be looked upon as the last act of muscle life. The next change is decomposition. Thus ends the story of what we are in the habit of calling the "lean of meat."

Fatty Tissue.—The structure which is called fat is not merely the compound of oxygen, hydrogen, and carbon to which chemists apply the name, but a tissue composed of cells filled with fat, properly so called, and joined together in a network of fibres. Fatty tissue forms a part of the meat—that is to say, it is mixed up with flesh; lying between muscles, and sometimes making its way in among the fine fibres, and occasionally into the muscle tubes, rendering the flesh soft and bulky; making, in short, tender, rich meat, but rather spoiling the contractile power of the muscle.

Besides being mingled with muscular structures fatty tissue is found filling up hollows in various parts, spreading out under the skin, and forming cushions on which organs may rest. It is also often interposed between parts which move over each other, or are subject to great pressure. The offices of fat in the process of nutrition have already been defined. It favours the building up of the tissues, and its place in this work cannot be entirely supplied by the so-called carbo-hydrates, gum, sugar, starch, &c., because it is not proved that they can be changed into fat. It also supplies carbon and hydrogen for combustion, and thus keeps up animal heat.

It must be remembered that the body requires about fifteen times more carbon than nitrogen, and if the oxygen in the blood cannot find enough carbon in the fat and carbo-hydrates, it will attack the albuminoids and get it out of them. But, further, fat as it exists, forming part of meat, is not only pure fat, the chemical compound of oxygen, hydrogen, and carbon, but is, as we have said, combined with white fibrous structure, which is properly classed among the nutritive substances (albuminoids). Therefore, while it is true that fat proper cannot supply the waste of nitrogenous tissues—cannot, that is to say, give them any nitrogen—the digestible fibres, which form in some parts of the body a considerable part of the fatty structure, can, and most probably do.

Allowing that fat has its place, and that a high one, in the living organism, and giving full weight to its qualities as an essential part of food, we do not intend to qualify a single sentence which we have used farther on in "running a muck" against the system of feeding stock which is current at the present day, having for its highest aim the production of the tissue which has the lowest value among food stuffs, and cannot exist to excess in the animal organism without inducing disease.

Skin.—Over the whole of the surface of the animal body is reflected a very dense but elastic membrane—the skin; which, with its covering of hair or wool, and outgrowths of horn and hoof, completes and perfects the external form. Among the organs of the body the skin occupies an important place. Its chief office is that of an excretory organ, but it also possesses the power of absorption, and has a great deal to do with the regulation of animal heat.

In describing the structure of the skin it is usual to speak of two parts—the lower portion, which is the true skin (cutis), having a basis of strong white and yellow fibres, in the meshes of which are inclosed the hair follicles, and the sweat glands, and those which secrete the sebaceous fluid, a yellow waxy substance which is often called the "yolk," as it is seen on the skin of the sheep.

On the surface of the true skin are nerves and numerous blood-vessels, forming a vascular layer from which the false skin or cuticle, which is composed entirely of cells of horny substance, is secreted. The cells of the cuticle as they reach the surface become flattened scales, which overlap each other and form a perfect protection to the sensitive and vascular parts beneath.

From the glands which are buried in the true skin tubes or ducts pass to open on the surface of the cuticle; those from the sebaceous gland generally go into the hair follicles and pour their secretion into them before it reaches the surface. The tubes which pass from the sweat glands take a corkscrew-like course through the skin.

Hair is formed by a process of cell-development in the bottom of the hair follicle, and the process may be said to go on during the life of the animal, new hairs being constantly formed to grow up and fill the places of the old ones which fall off.

Horn and hoof are constructed of cells very much like those which form hair; indeed, the structures are, in some instances, so closely allied, that it is difficult to distinguish between them when they are placed under the microscope.

The skin and its appendages have a profound interest for the stock-owner quite independently of their minute structure and functions. It is an object with the breeder to cultivate animals with skins of fine texture and mellow touch. And, in regard to the hairy covering, and the horns and hoofs, these are, in connection with them, points of form and colour which are much taken into account, in judging stock, as things of no mean character.

The subject of wool growing can only be alluded to here, as an evidence of the great importance which is attached to the cultivation of one of the appendages of the skin. To the physiologist wool is a matter of interest chiefly as an illustration of one of the forms which hair assumes in different animals. To the wool grower it is a material which has an infinite variety of characters and properties, all of which he can recognise, and to the cultivation and improvement of which he devotes himself. Wool growing is in short a science, and the utilisation of the product constitutes an extensive industrial system.

Functions of the Skin in the Animal Organism.—As an organ of secretion and excretion the skin has to do a large share of scavenger's work. In the form of sweat there is constantly passing off from the system in a gaseous state (insensible perspiration), watery vapour, carbonic acid, and organic impurities, which make themselves known by their odour. When the circulation in the vessels of the skin is excited by exertion or increased temperature of the air, sweat is given off in a liquid form, carrying with it certain solid matters in solution; to wit, salts of the blood, an albuminoid substance, and urea, the proportion of this latter compound being regulated by the action of the kidneys, which the skin is ever ready to help out of a difficulty. The sebaceous secretion which is given off in some animals, the sheep, for instance, in large quantity, has the effect of keeping the skin and hair moist and pliable.

The Skin as an Absorbent Surface.—Much difference of opinion exists even now as to the power of the skin to absorb substances which are applied to it. Some contend that the weight of the body is materially increased by immersion in a warm bath. Others assert, from direct observation, that the body may remain in water for many hours, without any absorption of the fluid taking place. Various chemical agents have been applied to the skin with the view to ascertain if they could enter the circulation, but the experiments have generally failed. It is, however, a matter of certainty that the skin can absorb gases, and it is probable that it also absorbs watery vapour. Everyone has heard the story of the jockey who trained down to the required weight, but on the morning of the race, being afflicted with thirst, he drank a cup of tea, and at once increased in weight six pounds. If the story is true, the increase of weight must have been due to rapid absorption of water by the vessels of the skin, the action of which was excited by the hot fluid taken into the stomach.

The skin does not, in the higher animal, give much aid to the process of respiration by absorbing oxygen; but it does something in this direction, and the two functions of absorbing good air and excreting bad are useful in the maintenance of animal heat and life, as proved by the results of covering the surface with a varnish which is quite impermeable by fluid. In such case the temperature falls rapidly and the animal dies.

Under certain conditions the absorbent power of the skin is exercised to the danger of the health of the animal. All kinds of putrid gases and foul emanations pass into the circulation in this way quite readily—a fact for the stock owner to take note of, suggestive of proper ventilation in stables, cowsheds, and milk stores.

Lastly, the skin may be considered as the membrane which binds the tissues beneath it into a compact shape; it protects the softer parts from injury; and as a non-conductor of heat by virtue of its hairy covering, it modifies the effects of changes of temperature outside the body, while the evaporation which is going from the surface prevents the undue accumulation of heat within the organism.

CHAPTER VI.

THE NERVOUS SYSTEM.

Sensitiveness—Manifestations in Animal and Plant Life—Movements in Drosera—Primitive Type of Nerve Organs—Ganglia and Nerve Fibres—Division of Ganglia into Systems—Highest Forms of Nerve Organs in Vertebrate Animals—Brain and Spinal Cord—Difference between Exito-motor and Voluntary Action—Consciousness—Reason—Instinct.

Sensitiveness.—Even the most simple forms of animals execute movements which seem to us to express likes and dislikes. In feeding, for instance, an animalcule will seize and retain certain particles within its reach, and reject others; and the most elementary organisms show that they are in some way affected by heat and light, and by contact with other bodies dead or living. This faculty of being influenced by agencies which act on the tissues is termed sensitiveness. The quality is shown in the most obvious ways by the higher animals, which have a full set of nerve organs; but it cannot be said that nerves are essential to its existence, nor, indeed, can it be claimed as a characteristic of animal life only.

In "Plant Life on the Farm," Dr. Masters has given us instances of the sensitiveness of plants to light, heat, moisture, and pressure, pointing out how, under one or more of these influences, some parts of the plant seek the earth, other parts the light; and how by modifying the degree of the action of the various influences the direction of the root or stem may be entirely changed.

Mr. Francis Darwin has shown us instances of remarkable sensibility in plants, coupled with the power of transmitting impressions which result in movements which appear to have a distinct object. Among other examples, he refers to the leaf of the Sundew or Drosera, which is, he remarks, slightly saucer-shaped, covered over with short glands, and fringed all round with projecting tentacles, which also terminate in glands. The glands secrete a sticky fluid which hangs in drops on them; hence the name of Sundew, because the leaves seem to be covered with dew in sunshine when other plants are dry. Insects are caught by the sticky secretion, and are also embraced and held fast by the outer tentacles, which possess the power of moving. When the insect has been killed by being drowned in the secretion, it is digested by the acid juice poured out by the glands, and subsequently absorbed.

The external or movable tentacles may be made to bend inward by an insect alighting either on the centre of the disc of the leaf, or on the sticky glands of the tentacles themselves. In the first case, when an insect is caught in the middle of the leaf, and the external tentacles bend in and surround it, we have a true transmission of stimulus: a message is sent as a message is sent along a nerve. The insect may be struggling to free itself, and will probably succeed in doing so unless the external tentacles give their help.

The external tentacles can be made to bend not only by insects or other objects placed on the centre of the leaf, but also by anything placed on the gland at the end of the tentacle itself. In this case the meaning of the movement is equally obvious. If a gnat or fly alights on one of the external glands it will probably escape unless carried to the centre of the leaf, where it will be also held by the small sticky glands.

Here also there is a true transmission of stimulus. The message has to be sent from the gland at the top to the place where the tentacle bends; a message is sent from the gland to the bending part of the tentacle, just as a message goes through nerve tissue from our skins to our muscles.

In this case the tentacle always carries the fly it has caught to the actual centre of the leaf. But if a fly has been caught by the disc of the leaf and not quite in the centre, then the messages are sent in accordance with the position of the fly, and all those tentacles within reach move to the point of irritation with marvellous precision. This transmission of messages is all the more wonderful because, as far as our powers of observation go, there is no special structure to convey the stimulus. It is true that waves of stimulation do travel with special facility along the fibro-vascular bundles, or what are usually called the veins of the leaf. But in this case, where tentacles converge to a given point in the disc of the leaf, this mode of transmission is impossible, because the veins are few in number and could not cause so nice an adaptation of movement. Moreover, stimuli can travel across a leaf of Drosera after the vascular bundles have been cut through, so that we have the wonderful fact of a wave of stimulation travelling with great accuracy, transversely through a number of cells with absolutely no structure like nerve fibre to guide the course in which the stimulus-wave shall flow.

One other curious phenomenon may be alluded to as showing the extraordinary power of stimulus-transmission.

If a piece of meat is placed on an external tentacle the gland on which it rests sends forth an acid secretion, and if a piece of meat is placed on the centre of the leaf the tentacles, as before said, bend in and ultimately touch it; but if the external glands are tested with litmus paper before they reach the meat in the centre they will be found to be covered with acid secretion, proving that not only had a message been sent to the moving part of the tentacles but also to the secreting cells of the gland.

One might find a parallel to this in the action of the human salivary glands. The gland nerves may be excited either by the stimulus of food placed in the mouth or by the voluntary action of the muscles of mastication. Here the saliva is poured out, although there is no food to act on, just as the Drosera gland secretes during the movement of the tentacle before there is anything for its secretion to digest.

Having briefly considered the transmission of stimulus-waves as shown in Drosera, I will pass on to consider what manifestation may be found of the other general properties of nerve-tissue, the property which I have called exploding power. It is chiefly manifested in Drosera by the extreme sensitiveness of the glands on the external tentacles. It is found not to be necessary to place meat or insects on the glands, but that bits of glass, wood, paper, or anything, will excite them. Smaller and smaller atoms were tried, and still the glands were found to be sensitive to their presence. At last a minute piece of human hair, about one-hundredth of an inch in length, and weighing just over one-eighty-thousandth of a grain, was placed on the gland of a tentacle, and caused unmistakable movement. The case is yet more wonderful than it sounds, because the piece of hair must be partly supported by the thick drop of secretion on the gland, so that it is probably no exaggeration to say that the gland can perceive a weight of one-millionth of a grain. This degree of sensitiveness is truly astonishing: it seems to us more like the sense of smell than of touch; for to our most delicate tactile organ, the tongue, such atoms are quite imperceptible.

The power which Drosera has of perceiving the presence of ammonia is perhaps still more astonishing. A solution of phosphate of ammonia in pure distilled water in the proportion of one part to over two million parts of water caused inflection of the tentacles. One may form an idea of this result by making a solution of a single grain of the phosphate and thirty gallons of distilled water, and then finding out that it is not pure water. Considering the water supply which we at present enjoy, we may well be grateful that our senses are duller than those of the Sundew.

As examples of simple sensitiveness these facts are sufficiently striking, but the powers of discriminating between different kinds of stimuli are equally curious. The tentacles having proved so extraordinarily sensitive to light bodies resting on them, one would expect that the slightest touch would make them bend. But it is not so. A single rapid touch, though it may be violent enough to bend the whole tentacle, does not cause inflection.

The meaning of this is clear, for in windy weather the glands must be often touched by waving blades of grass, and it would be useless labour to the plant if it had to bend and unbend its tentacles every time it was touched. It is not excited except by prolonged pressure or quickly-repeated touches. This is also quite intelligible, for when an insect is caught on the sticky secretion of the gland it will give a somewhat prolonged pressure or a number of kicks to the sensitive gland, unless it flies away after a single struggle; and in that case also the tentacle will be saved from unnecessary bending.

In another carnivorous plant Dionæa, the specialization of sensitiveness is exactly the reverse: thick and comparatively heavy bits of hair can be cautiously placed on the sensitive organs without causing any movement, but the delicate blow received from a cotton thread swinging against the hair causes the leaf to close. Dionæa catches its prey by snapping on it like a rat-trap; there is no sticky secretion to retain the insect as in Drosera till the slowly-closing tentacles can close on it. Its only chance of catching an insect is to close instantly on the slightest touch. The specialization of sensitiveness in Dionæa is therefore just what it requires to perfect its method of capture.

In describing the sensitiveness of Drosera and Dionæa I wish rather to insist on a wide and general similarity to the action of nerves. There may be said to be an analogy between the specialization of extreme sensitiveness in Drosera and Dionæa and the nervous tissues of animals because these properties play the same part in the economy of the plant that is supplied through some kind of nerve machinery in the higher animals.

It might be expected that the remarkable manifestations of sensibility, and even of what may be called habit and memory, in plants, would be associated with structures which might be compared with nerve-organs in animals; but no such structures really exist in plants; and when we remember that sensibility and some power of discernment are shown by animals in which no distinct nerve-organs can be traced, we are led to consider that the property, like that of motion, is inherent in living matter.

Primitive Type of Nerve-Organ.—The most simple kind of nerve apparatus in the lower form of animals consists of a single mass of nerve-substance (ganglion), with nerve fibres. The ganglion is a nerve centre, and is composed of the two essential constituents—grey cellular matter and white tubular matter. Nerves which proceed to and from the centre are chiefly made up of white substance inclosed in a fibrous sheath. Some, however, have a considerable share of grey matter in their structure. Nerves are, strictly speaking, conducting organs, and they proceed from the tissues to the nerve centre to carry impressions, and from the centre to the tissues to stimulate them into action.

In accordance with the simplicity of arrangement which is found in the earliest type of nerve-organs, the functions which are performed are simple in their nature ; but they nevertheless are closely related to the actions which are observed in the higher animals.

A nerve centre (ganglion) receives impressions which are communicated to it from the structures in which the nerves arise. It then transmits the message, whatever may be its purport, to the part to be acted on by means of another set of nerves arising in the ganglion. This double transmission is called reflex action, and is constantly going on in the highest animals as well as in the lowest.

A form of nerve organs which is observed as we ascend from the lowest types, consists of several ganglia forming a chain on each side of the body, connected by branches of nerves. Numerous other branches go to and from the centres in connection with the various parts of the organism. In this method of arrangement there appears to be a division of function. Certain of the small centres and their nerves are apportioned to the digestive, breathing, circulatory, and other organs and parts of the animal body.

Nerve Organs in Vertebrate Animals.—Animals which have a back-bone (spinal column) possess the most perfect form of nerve organs. In them the ganglionic system of nerves exists, as it does among the invertebrates, but is more complex in arrangement, with the addition of a large nerve-organ—the brain—and a long cord (spinal cord) extending from it, through a canal which passes the whole length of the chain of bones forming the spinal column.

The brain is a large mass of nerve substance including a number of distinct nerve-centres, from which nerves are sent out, or into which they pass. Forming an important part of the system of nerve organs are the organs of special sense, popularly known as five in number—Touch, Taste, Smell, Sight, Hearing. All these senses are due to certain impressions made on the nerves of the several organs, and by them transmitted to the brain, so that the animal may become conscious of them.

The spinal cord may be considered as a double chain of ganglia connected together by intervening nerve substance, extending from the medulla at the base of the brain.

From the brain, the medulla, and the spinal cord, nerves pass in pairs, one on each side, to all parts of the body; and other nerves arising in the tissues enter these nerve centres.

The in-going nerves are generally sensory nerves, and convey impressions from without to the spinal cord; while out-going nerves are usually motor nerves, which carry directions from the centres to the tissues.

Functions of Nerve Organs.—Reflex action is the most important function of the nervous system. What is meant by reflex action in the simple forms of nerve organ has already been explained, and it may be stated at once that the function only differs in its results in the most perfect forms. The action really is the conveying of an impression from any point to a nerve centre by a sensory nerve, and the reflecting of it back to the same parts or some other part, along a motor nerve, for the purpose of causing some action which is in some way rendered necessary by the impression made on the sensory nerves. A familiar example will make this clear. If the palm of the hand of a sleeping person be touched, the fingers of that hand will close. It cannot be said that the sleeping person closes them, because he knows nothing at all of what is going on. The closing is effected by reflex or excito-motor action in this way. The touch on the palm makes an impression on the sensory nerves of the part, which they at once carry to a nerve centre in the spinal cord. After a rather intricate journey across to one set of columns and down another, all done with lightning-speed, the impression comes back along a motor nerve to the muscles of the fingers and tells them to contract, which they do, and the fingers are closed. This is all that happens, but it is really a very important "all"—quite incapable of explanation.

The mere sending of a direction along one set of fibres and back along another is nothing; but in the case before us, and in thousands of more curious instances of reflex action, no particular direction is sent. The nerves of the palm are touched. Why should the consequence of this be a message from the nerve centres to shut the hand? Why not to open it? or sometimes one, and sometimes the other? No reason can be given. We know that all the functions of animal life—digestion, circulation, respiration, secretion—are kept in action in this way, but we do not know how the effects are brought about.

Voluntary actions are quite distinct from reflex, and although the highest form of nervous structure is necessary for the production of voluntary acts, they are more intelligible than those which occur in the excito-motor system.

To explain a voluntary movement, the example just given, with a little change, will do. The person is not asleep now, but wide awake; and we touch, as before, the palm of the open hand. But we are by no means sure what will happen now; possibly a number of unexpected events, arising out of the circumstances. The individual may be surprised or angry, and may resent the act in speech or movement. The only thing of which we are sure is, that whatever is done will be the consequence of intention on the part of the person experimented on. If the hand is closed it will be by a distinct determination to close it, originating in the brain, and carried from it to the muscles.

Reflex actions are uniform, in fact instinctive in their nature, and what has been seen to occur once may be fairly expected to happen again under similar conditions. But as soon as the reasoning faculty is introduced we are all abroad as to consequences. Whether an attempt to cause contraction of a muscle by stimulating a sensory nerve in a conscious animal will end in the object being gained, or in the animal running away or kicking the experimenter off his feet, are things which are among the "glorious uncertainties of physiological law."

In connection with the subject of voluntary movement as distinct from reflex, it may be noticed that many of the movements which the higher animals are constantly performing, although under the direction of the will, are by frequent repetition rendered automatic—self-acting. To this order belong many actions which come under the head of habits—actions of which we are unconscious until some candid friend calls our attention to them, and suggests, perhaps, that they might be discontinued without loss to ourselves or others. In this situation there is sometimes a grain of consolation to be extracted from the observation that our friendly critic is himself addicted to the habit to which he objects so strongly, and of his own indulgence in which he is happily ignorant, although the action may be properly classed as intentional, or coming under the government of the Will.

Any attempt to grasp the subject of the highest functions of the brain, Consciousness, Mind, Reason, in their various phases and forms of expression, would lead us into the hazy regions of psychology, and we accordingly forbear. But we may remark, just by the way, that the actions of the lower animals—as we choose to call them—those with brains and those without, constantly force us to try to solve problems to the solution of which we have no clue: many of the instinctive actions which are performed by invertebrate animals (animals without brains), suggesting what, in a vertebrate animal, we should call intention or reason—witness Sir John Lubbock's stories about bees and ants.

But we may cease to wonder at the semblance of intelligence displayed by insects when we read Mr. Francis Darwin's story of the actions of plants seemingly arising out of some dim mental processes. Speaking of the sleep of plants, he says, it "consists in the leaves taking up one position by day and another by night, the two positions for night and day following each other alternately." "The common Sensitive-plant (Mimosa) is a good example of a sleeping plant. A most marked character of the night or sleeping position is that the leaflets, instead of being spread out flat as they are in the day, rise up and meet together, touching each other by their upper surfaces.

"In Norway, the region of continual day, the Sensitive-plant remains continually in the daylight position. We might fairly expect, therefore, that we should be able to produce the same effect by artificial light constantly maintained. This experiment has in fact been made by A. De Candolle, Pfeffer, and others, with perfect success. But before the leaves come to rest a remarkable thing takes place. In spite of the continuous illumination the sleeping movements are executed for a few days exactly as if the plant were still exposed to the alternation of day and night. The plant wakes in the morning at the right time and goes to sleep in the evening, the only difference between these movements and those of a plant under ordinary circumstances is that under constant illumination the movements become gradually smaller until at last they cease altogether. When the plant has been brought to rest, it can be made to sleep and wake by artificial alternations of light and dark. This fact seems to me extremely remarkable, and one which in the domain of animal physiology can only be paralleled by facts connected with habit. And if it is allowed that the Sensitive-plant is subject to habit (and this cannot be denied), it must in fact possess the germ of what, as it occurs in man, forms the ground-work of all mental physiology.

"I will mention one more fact in connection with the movements of the Mimosa in which the formation of habit is illustrated. Every one knows that a noise regularly repeated ceases to disturb us; that one becomes habituated to it and almost ceases to hear it. A boy fast asleep inside an iron boiler whilst riveting is going on is an example of this power of habituation. The same thing occurs with the Sensitive-plant. A single violent shake causes the main stalk to drop and the leaflets to shut up: in a minute or two the leaf recovers and will again re-act on being disturbed. In order to test the power of habituation I fastened one end of a thread to the leaf of a Sensitive-plant and the other to the pendulum of a metronome and placed the plant at just such a distance from the instrument that it received a pull at every beat. The first shock caused the leaf to shut up, but after a few repetitions it became accustomed to it, and I had the curious sight of a highly sensitive plant unaffected by a series of blows. In Nature this power no doubt enables the plant to withstand the constant shaking of the wind."

With his mind in a perfect state of discipline from the perusal of the foregoing remarks on the marvels of Plant

Life, the reader may be able to bear one more quotation on the subject of "sensitiveness." The paragraph is from the *Lancet* in 1878, forming part of a review of a treatise on botany, edited by Dr. Masters. The writer refers to the advantages which the student of plant-physiology possesses, in the following terms :—

"More fortunate than his brother, the physiologist, the botanist can make what experiments he pleases without fear of legislative enactments, or dread of wounding the susceptibilities of an undiscerning public. He may bore holes into or ring his trunks, may shut his leaves up in the dark, may treat them with poisonous reagents, may irritate his Sensitive-plants beyond endurance, may experiment on the flow of the sap, or arrest it altogether, may burn, electrify, or asphyxiate his subjects, and yet escape unscathed without awakening even a sigh of pity or the feeblest remonstrance. Yet who will say that some diffused nervous influence does not exist, some dim consciousness which a future generation, with wider sympathies, may insist on being respected." Is all this too romantic for this matter-of-fact age? Quite possibly it is. In any case the next chapter deals with the things of common farming-life—with occasional comments by the way, which the reader is entreated to bear, with as much patience as he can muster.

CHAPTER VII.

THE BATTLE OF LIFE.

Conflict a Law of Nature—Strife in the Inorganic World—Struggle for Existence in Plants and Animals—Survival of the Fittest—Natural Conditions affect the Propagation of the Race—The Maintenance of Life and the Development of Structure—Domestication leads to the Survival of the Unfittest—Care of Feeble Subjects tends to Hereditary Disease.

It is not possible perhaps to realise the full force of the words "the whole creation groaneth and travaileth in pain until now;" but they suggest the idea of conflict, and the thoughtful student of Nature is not long in finding out that he is working in a "world of strife." Even the atoms of the "lowly dust," Mr. Ruskin teaches us, in words which almost force us to believe what he writes, have their life struggle; and we are led on to sympathise with "crystal virtues and quarrels, crystal caprices and sorrows," and lastly to contemplate the idea of "crystal rest and death."

In Dr. Masters's "Plant Life" we are introduced to the battle-field of the "grasses" and shown how merciless each plant is in taking every inch of vantage ground to its own profit, without care for the lives of its neighbours, seemingly sometimes with stern resolve to strangle out of existence every green thing which may come in the way of its own progress.

Among animals under natural conditions the "battle of life" is fought incessantly and with effects which could not be imagined, but which hard-workers like Mr. Darwin have brought to the light.

One short sentence expresses the whole results of the struggle for existence—"The survival of the fittest." Philosophers have spent long lives in working out the conclusion which is stated in these terms, and it is quite worth while to try to make out the meaning of words which are clearly intended to convey so much.

What is meant by "The survival of the fittest?" The writer is deeply interested in making this clear, because he intends to show, by-and-bye, that there is such a thing as the "survival of the unfittest," which is quite a different matter.

When philosophers talk about the "fittest," they presumably mean that which is best adapted to exist under the circumstances in which it is found in Nature; and by Nature they may be supposed to mean the world as it exists without any of its laws or conditions being disturbed by the interference of man. More plainly, Nature means "the wild state," in contrast with what is meant by "the state of domestication." It is not necessary to contend that this is the only, or even the best definition of Nature; it is only proposed to accept it as a convenient one for the present purpose, which is to distinguish between natural and artificial conditions of existence.

Putting the case in quite distinct terms, it is asserted that, under the operation of the laws of "Nature," the result is the "survival of the fittest." A second proposition—the author of these pages ventures to add, entirely on his own responsibility, not asking his readers to accept it without proof—may be thus stated :—"The whole result of the operation of the laws of Domestication is 'the survival of the unfittest.' " Most likely the breeder of pedigree stock who may chance to grasp the full meaning of the statement will feel at first no alarm. If, however, he desires to retain his placid state of mind, he is warned not to follow the argument to its conclusion, because he will find therein a good deal of the stern logic of facts, which are opposed to his rule of practice; and because, further, the subject is a "hobby" of the writer, and he intends to ride it presently at a break-neck pace, not caring much how many obstacles in the form of prejudices or fondly cherished beliefs he may knock over in the way, knowing very well that most of them, bad and good alike, will get up again not much the worse for the tumble, and that things will go on just as before.

Exactly twenty-one years ago a paper on "Precocity of Development," by the present writer, appeared in the Journal of the Bath and West of England Society. The views therein expressed are very much those which are advanced here. This will appear from some of the sentences which are quoted from that paper with the intent to show that the writer does not offer startling statements without having allowed himself time for consideration.

Taking the first proposition—that under natural conditions the tendency is to the survival of the fittest—it may be considered in regard to the effect of natural selection on the propagation of the race, and on the maintenance of life in the struggle for existence.

Principles of Breeding is a title which heads many an essay in agricultural journals. Nature has only one principle, which was the principle of life of the old Borderer—

"Let him take who has the power, and let him keep who can." In these days we get a glimpse now and then, in deer parks and in the few herds of half-wild animals in different parts of the country, of the fierce contests of bulls and stags and rams for the proud position of "master," which may be held just so long as the beasts remain the strongest. By-and-bye the stronger comes, and the former king is banished from the scene. This fight for the right to propagate their race among half domesticated animals can give but a feeble idea of the war to the death which occurs among the males under natural conditions. It is a maxim of chivalry that "None but the brave deserve the fair." Nature puts on one side the polite suggestion as to deserts, and sternly announces as a law, "None but the brave shall have the fair." To the applicant for honours the simple decree is uttered, "Do you desire to be the parent of a vigorous progeny? Prove your power by force of arms, or, failing, retire into a fitting obscurity."

It would be a mere waste of time to proceed to prove by reference to details that under the circumstances stated the production of a hardy race is secured, so far at least as the male parent is concerned. With respect to the female the object is gained without any unfeminine resort to physical force, by the influence of all the surroundings under which the animal lives, conditions which we shall see all tend to the benefit of the strong and the destruction of the feeble.

Born of healthy parents—the idea is new to one who has mastered the system of breeding as now conducted—the young animal starts fair in the race. But Nature is by no means inclined to pet it; just the contrary in fact. From the first the creature must mainly depend on itself, at least as soon as it leaves the fostering care of its mother, and often before then.

The effects of natural conditions on the maintenance of life are now apparent. If the young animal is healthy and strong it is able to resist the adverse influences which are brought to bear on it in its search for food, or escape from its enemies. Failure of food, atmospheric changes, accidental injuries, disease possibly—but on this point little is known—are among the tests of hardihood which Nature applies, a system under which only the strongest can survive.

Struggle for Existence.—Mere preservation of life is only possible to the hardy under natural conditions, but the struggle which is forced on the animal during its whole life leads to something more than the growth of structure and the maintenance of life. The reader who will take the trouble to study "Darwin's Origin of Species," will see how external conditions affect form and habit. How far the rather sweeping deductions which have been drawn from the facts can be defended is still a matter of debate, but as to the facts themselves there can be no dispute.

It is certain that constant and perhaps excessive use of certain organs leads to their growth out of proportion to the rest of the structure, and on the converse side of the picture is the patent fact that organs which are from any cause thrown out of use gradually shrink and at last become mere rudimentary structures, of little or no use to the animal. Again, it is true that a defect or excess of development is not only continued, but is rendered more marked in successive generations; and at last a new variety or a new species of animal will be the outcome of the influence of a change in the conditions of life.

To pursue the subject further would encroach too much on the space which is to be occupied by other matter; but enough has been advanced to show that in a natural state the fittest survive, because the weak succumb to adverse influences. The fair conclusion is that Nature has no idea of pity for the helpless, but rather contempt. Her notion of life is vigour, health, perfect adaptiveness to the surroundings. The organism, which cannot comply with these conditions, ceases to play a part in the scheme.

Life in Domestication.—Leaving the subject of Animal Life under Natural Conditions, we have to consider the next proposition, which is, that the tendency of the Artificial Conditions of life in Domestication is to "the survival of the Unfittest." It can hardly be questioned that all means which act by preserving the lives of diseased, weakly subjects, permitting or encouraging them to propagate their kind, are calculated to produce a feeble race. It is a trite saying, that it is natural to foster the sick and helpless! It is nothing of the sort. Our hospitals for incurables and asylums for imbeciles and lunatics are the outcome of centuries of education, religious, moral, and political. In Nature such provisions have no place. If the law of mercy to the feeble were once established in the natural world animals would soon become extinct. They owe their existence to the operation of an entirely different law, which in its results is "wholly beneficent because wholly inexorable" But, to descend from the general to the particular, we shall find no difficulty in seeing how the Law of Artificial Selection operates in our cultivated breeds of farm animals.

In the essay on "Precocity of Development," to which reference has been made, the following passages occur:—"Disease in the wild animal finds its limitation in the general probability of the subject falling a victim to the adverse influences which he is incapable of combating. In domestication these adverse influences lose much of their power, or are sensibly modified by the adoption of measures intended to combat their effects. Defects which, in a natural state, would render the animal incapable of living, and which, if perpetuated, would ultimately lead to the extinction of the race, are, under the new conditions, fostered and extended, and take the name of 'hereditary' or 'transmitted' diseases running through whole generations, or occasionally ceasing for a time only to burst out again with renewed violence.

"The property of acquiring early maturity is transmitted as other qualities are; and in the endeavour to perpetuate peculiar excellencies, the temptation to breed from animals of the same family is very strong; in fact, these artificial qualities can be cultivated to the highest point by no other means.

"Accustomed as we are to speak of the great improvements which have taken place in the various cultivated breeds, it is not to be supposed that we can at once accept the idea that all the work has been in vain. If by rapid improvement of the breeds of cattle, sheep, and pigs, we mean rapid growth of the animal, the development of fat and flesh, premature maturity at the expense of the perfection of the organism, then the system has succeeded. But to say that our efforts have tended to improve the health of our animals, to diminish the liability to disease, is to make an assertion which is opposed to all the evidence bearing upon the subject.

"We are ready to admit that remarkable results have followed the efforts to improve the breeds of farm animals, results not altogether satisfactory, but not the less decided. We accept the proof of what can be done by attention to a definite object; but we do not the less contend that the system has been carried too far. The principle has been all along that of the railroad, the struggle to drive onward rapidly at all risks, even without considering them. The cry has been for the animal that will be the first ready for the carriage, the saddle, the dairy, or the butcher; and so far the demand has been answered—at what cost we have endeavoured to show."

Whatever force attached to the above words more than twenty years ago has not been lessened in the intervening period.

By the system of artificial selection man assumes the position which, in the wild state of animal life, is taken by natural law, and he acts from different motives and on different principles. To begin with, he does not demand that the male shall prove his vigour by his power to conquer or demonstrate his soundness by his resistance to hardships. The animal possesses the perfection of form as his owner understands form, his pedigree is unexceptionable, he cost a large sum of money, and his progeny will command a high price in the market. What more can be desired by a successful breeder of high-class animals? Any question of taint of constitution, which is certain to be transmitted and most probably in a more intense form, is carefully avoided, or at any rate is not seriously suggested. The animal selected may come of a race which is wanting in power to resist the common or special causes of disease, a fact which would be ascertained on inquiry, but in practice no such inquiry is ever instituted, probably is not even thought of. And what are the results in the improved or cultivated breeds? Tuberculosis—which is a similar disease to consumption in man—extends its area every year among our best cattle, to the risk of the extinction of the variety and the great damage to public health.

The liability to suffer from any prevalent disease is in the cultivated breeds most marked, and the effects of even the most simple affection (as they used to be considered) are so serious that the doctor has no chance of fighting the enemy, because his patient succumbs at the outset; and it has got to be a proverb on the farm that the "butcher is the best doctor." So much for the system of artificial selection in breeding.

If the system of breeding by artificial selection is open to question, what is to be said about the system of artificial feeding?

Food fulfils its purpose when it supplies the animal organism with material for the repair of its tissues, and sustains the structures in a normal condition; but in domestication the feeder of stock determines to what extent this object shall be carried out; and in regard to one class of animal on the farm—the horse—he is ready to do the best he can to keep the animal in a state of health and vigour, in order to use his powers for his work or pleasure.

The horse has the advantage of being supplied, so far as his master's judgment goes, with food which is calculated to support his system and maintain it in a healthy state;

and generally this animal on the farm is placed under the most favourable circumstances which domestication affords for the preservation of his health and soundness.

All the animals of the farm, excepting the horse, are fed with some special object, which is first. Their vigour, muscular force, powers of endurance, and strength of constitution, occupy the second place, even in the rare event of being allowed to enter into the calculation at all.

In the next chapter the subject of feeding for early maturity at all hazards is dealt with in regard to details, and at the risk to the writer of acquiring the reputation of being somewhat "crotchety" on the point.

A distinguished pathologist lately remarked that he had a high opinion of the value to society of a man with a "crotchet," "because," he said, "there is always a good deal in it;" and the idea, whatever it may be, is thrust forward so persistently and dragged into every discussion with so much enthusiasm, and every fact is so tremendously exaggerated, that people at length begin to believe a part; and finally the process of inquiry goes on, and it is found that the crotchet really has something in it worth more attention than it has had given to it. The author does not mind if the stock-owner will consent to deal with his "crotchet" in the way just suggested. On the sure ground of observation and experience he ventures to assert that there is "something in it." But it may be asked, if there is something in it, what is to be done? Is the whole system of artificial selection to be abandoned? Is early maturity a superstition to be discouraged? These queries are worth a chapter to themselves, in which the writer hopes to show how to do wrong, within reasonable limits, without having to pay all the penalty.

CHAPTER VIII.

EARLY MATURITY OF LIVE STOCK.

Practice in Breeding and Feeding Live Stock on the Farm—Breeding for Early Maturity—Inherited Capacity for Laying on Fat—Rest a Condition of Fattening—Exercise necessary for Formation of Muscle—"Baby Beef" and Mutton—Modified form of Muscle in Fat Animals—In the Artificial System of Feeding the conditions favour the deposit of Fat—Statement of Results—Breeding Pedigree Stock not a Part of Agriculture.

Practice *versus* **Science.**—A promise was given in the last chapter that every-day matters of farm life should have their share of attention in this one. The promise is not forgotten. But, before it is fulfilled, it may be worth while to devote a few minutes to the subjects which have been dealt with in the preceding chapters. The theme of this chapter is in reality practice, not with science, but against it; and before we turn our backs on scientific teaching and discuss a system of breeding and feeding "totally at variance with Nature," let us pay science the compliment of a parting glance, and even pause to listen to a few last words.

"The whole Story shortly told."—At the commencement science had something to say on the mysteries of **Life** and **Death** in the animal and plant worlds. Then she showed us how a mass of transparent jelly (bioplasm) lives and performs all the essential vital actions. Next we were told how a single living mass, of extreme smallness, in the mature ovum of the higher animal, becomes, under certain conditions—contact with the sperm-cell of the male being one of them—the centre in which curious things happen. The single living mass divides into many portions, forming a cluster of cells which arrange themselves in perfect order, and end by becoming bones, flesh, fat, blood, heart, lungs, stomach, and intestines, and in short everything which goes to make up an animal.

Science, having told us how the animal is developed out of a small particle of living substance, went on to speak of the structures and uses of the organism. We saw that the animal grows and moves; that it eats and drinks, and keeps warm, even in cold weather. Further, it was made clear that animals excrete waste products without getting any less—it may be getting bigger meanwhile; and we were led to inquire into the details of the various processes by which loss of structure is supplied by new matter—old and worn-out tissues are got rid of—heat is kept up; and the body is maintained in a state of balance. This inquiry brought to our notice several organs which are engaged in doing special work; each seemingly being entirely occupied with its own concerns, but in reality working in concert with the rest: the digestive, circulatory, breathing, absorbing, and excreting organs, all acting with a common object under the direction of the nerve organs.

By the action of the digestive organs the food is reduced to a condition which fits it for nutrition. The absorbent vessels take up the dissolved and prepared constituents and convey them into the blood stream. By the aid of the heart, which pumps the blood through the vessels over the body and back again, the nutritive elements of the food are brought in contact with the tissues; which, in the exercise of their wonderful power of selection, take what they require for their own support and leave the rest. The breathing organs are constantly employed in getting a supply of fresh air at short intervals; and, during the circulation of the blood through them, some of the all-important oxygen of the air is taken up by that fluid and carried into the tissues, where it unites with carbon and hydrogen, and sets up combustion, the results being heat, carbonic acid, and water.

Waste or effete matters, including the products of combustion, must be removed from the organism : they are not merely useless but poisonous, and accordingly we find that a very complete arrangement of excretory organs exists for their removal. First there is the great main-drain, the intestinal canal : through which passes all the undigested or unused food, mixed with broken-up cells from the mucous membrane ; and the excess of fluids secreted by the numerous glands which open into the canal. This mass of effete matter in the form of manure represents to the farmer a considerable proportion of the value of the food which has supplied nutriment to the animals ; and is now to become the food of plants.

Waste matters which are soluble are got rid of by the aid of the kidneys, in the form of urine, and by the skin, with its vast system of sweat-glands ; while the lungs and the skin together excrete carbonic acid and all organic impurities which assume the gaseous form.

Looking at the animal fully formed and in a state of perfect balance, we saw all the functions of life in action : —the bony frame-work supporting the soft textures, or forming boundaries of cavities to enclose them ; muscles acting in obedience to the will, or under the stimulus of the excito-motor nerves; the heart beating with sufficient force to send the blood its destined round; the lungs expanding to let in the air which is to carry new life to the elements of the tissues; heat being eliminated to be resolved into force; wasted textures rebuilt with the products of digested food, and the old matters swept away to make room for the new—all the machinery self-acting, working smoothly day and night, in perfect accord with the external conditions, showing no sign that it was ever meant to stop. But, "Alas! for the life that lives but a year, or a month, or a day," we soon saw that continuance of existence means continued correspondence with life's surroundings, which are always changing, and often taking the form of "adverse influences."

Our "bird's-eye" view of animal life under two very different sets of conditions forced us to accept the fact, that in Nature everything tends to the benefit of the strong and the extinction of the weak. The sentence is, Fall out of "correspondence with your environment," and die; "if life is worth having, fight for it." The outcome of this stern system is perfection of organisation and perfect life. On the other side of the picture we saw the animal under the ban of civilisation, having nothing to fight about,—no life worth speaking of to struggle for; compelled to take the food provided for it, with as much fresh air as might be thought good for it; "cabined, cribbed, confined,"—a meat-making and manure-forming machine; "a tub with a hole in the bottom," (these are the very words of a practical breeder and feeder of stock,) —"a tub with a hole in the bottom," which must be filled up by pouring into it quickly, because "the quicker you pour in, the less the waste." With this maxim for a text there is nothing to prevent us from at once plunging into the practical part of our subject.

Principles of Breeding for Early Maturity.—It is well to start with a clear idea of the object which the breeder of farm stock has in view, and perhaps it may be sufficiently indicated in the two words "Early Maturity." The breeder's aim is, and has long been, the production of a race of animals with an inherited capacity for assimilating food at an early age and under artificial conditions of existence.

Mr. Henry Evershed, in his pamphlet on Early Maturity of Live Stock,* which every farmer should read, tells us that in 1878 he contributed a paper to the Journal of the Royal Agricultural Society, in which he gave the first published account of the production of what was then called "*baby beef.*" We put the words in italics, as they are worth marking; and if we add the terms "*baby mutton,*" the two will fairly express the real aim of the forcing system, the results of which, stated as plainly as Mr. Evershed states them, amount to this:—"Remarkably ripe, handsome carcases of beef from bullocks under twenty months old; lambs sold as mutton at seven and ten months old," of which the butcher writes,—"Never, during my experience of over forty years, have I had any sheep equal to them in weight, quality, and flesh at their age."

These specimens of "premature maturity" were manufactured according to an improved method; and to obtain the like results the same lines must be laid down and fol-

* "The Early Maturity of Live Stock." By Henry Evershed. London: Horace Cox, *Field* Office, Strand, W.C.

lowed. To begin with, Mr. Evershed remarks,—"It is the general experience that breeding from ewe lambs induces early maturity." It is only an extension of the principle to add "heifer calves" and "sucking pigs," to complete the series of "baby parents" from which are to come the baby beef, mutton, and pork of the future.

In defence of the system of breeding from immature parents, in order to develope a tendency to early maturity in the offspring, the writer whose words we have quoted urges, "That, in pursuing a system of breeding totally at variance with Nature, in which natural selection is replaced by that which is artificial, and unaccompanied by any struggle for existence, we must be guided by *facts* rather than by *theory*." Again we introduce italics which are not in the original. Facts by all means let us have; not only the facts of "baby beef" at twenty months, and "baby mutton" at seven months, but those more grave facts which it is the province of the pathologist to observe and record.

After all, from the point of view of the breeder for "early maturity," there is perfect consistency in the idea of breeding from young animals, the best specimens of which are sure to be selected; those which exhibit in themselves the precocity which is to be encouraged. Scientists are well aware that the most certain way to secure the development of any artificial instinct or quality is to breed from parents in which the instinct or quality is apparent. "Like produces like," is the practical breeder's sure maxim. Mr. Huxley, on the side of science, expands the maxim in these words, to which we shall have to refer more than once before we finish this subject:—"The one end to which, in all living beings, the formative impulse is tending—the one scheme which the Archæus of the old speculators strives to carry out—seems to be to mould the offspring into the likeness of the parent. It is the first great law of reproduction, that the offspring tends to resemble its parent or parents more than anything else:" *i.e.* resemble them in structure and functions—in good or bad qualities—in excellencies or defects. And with the meaning fully grasped, this sentence is an epitome of the science and art of breeding.

Precocious parentage is a phase of artificial selection which is yet in its infancy, and it is well to remember that there are two sides to the picture, one of which has been exhibited, and the other turned to the wall. Great things have been done, we are told, by breeding from ewe lambs, but the flock-masters on the Hampshire Hills find that the tender mothers cannot stand the exposure; and in the circumstances it answers better to use ram lambs to older ewes. Only when special care can be taken to protect the mothers does it answer to use young parents of both sexes; and it seems to be admitted that when ewe lambs are used for breeding, they do not afterwards acquire their full growth. It yet remains to be seen how far this system can be carried in breeding farm-stock with the view to early maturity, that being at present the only point with which we are concerned.

Feeding for Early Maturity.—Having started fairly by selecting precocious parents, the next thing is to push on the progeny without a moment's loss. The old-fashioned system of letting the mother take care of her young is an "exploded error." To make "baby beef" the calves must be weaned at birth, because they more readily adapt themselves to an artificial system of feeding. It is, however, admitted that calves are most successfully managed when they are allowed new milk for several weeks, at the rate of four to eight quarts per day up to a month old; afterwards skimmed milk with boiled linseed or meal is substituted. Hay is given as soon as the animals can be induced to eat it, and, in addition, a pound of linseed cake daily, in order to "develope the first stomach." In winter, root-feeding commences with an increased allowance of cake, which is continued until the animal is ready for the butcher at twenty months.

A somewhat different system of feeding calves for early maturity was referred to by a writer in the *Field* in December, 1884. "The calves were allowed to suck their dams until the cows were again close at calving, *i.e.*, about eleven months. This kept the cows in rather lean condition, but it made a grand job of the calves. At the age of eleven or twelve months they were not only big stock, but very fat—not veal, but the firmest of beef. Than last year's crop of twenty-five, the writer hereof never saw so pretty a lot—so ripe at the age. The calves shared with their dams the summer keep of good grass, and the winter fare of meadow hay, roots, straw, cake, and grain. To make way for the newly dropped calves, the yearlings were sold to the butcher at from £20 to £24 a head, representing nearly £2 per head per month's keep. The dairy produce of the cows, so near a town, might have approached that figure; but there would have been much more labour and attention to details involved." This is a form of the forcing system which is not quite so much "at variance with Nature." It is, however, at variance with the typical method which Mr. Evershed thus describes:—"A calf well reared is a long way on the road to baby-beefhood. I shall only add, that calves must lie dry and warm, in well ventilated sheds (which in summer should be cool), in lots not exceeding half-a-score, so as to avoid the diseased lungs or other evils which arise from their lying in heaps one on another, and inhaling each other's breath. If good cool pastures are available, the calves will probably be allowed to run in them in summer, and cut their own green-meat; but, in order to attain the earliest possible maturity, they must not quit their sheds summer or winter, remaining indoors placid and undisturbed."

In proof of the success of this plan, in its financial aspect at least, it is related that "an experiment was tried in Sussex in comparing two lots of calves, one of which remained in the sheds, while the other was summered in the pastures, the 'corn' in each case being alike; and the former lot was worth 30*s.* per calf more than the latter, which considerably exceeds the cost of labour in feeding them."

It is obvious that the indoor system allows of the cultivation of baby beef in a smaller space than would be required for pasture feeding, and in this respect it has an advantage.

Nutrition under the Forcing System.—At this point the author is conscious that the intention of turning his back on science with which he began this chapter is going the way of all good intentions, and there is no help for it. A little physiology must come in to help him in solving some of the problems which are now to be set and worked out.

Under any system of feeding, natural or artificial, the food supplied must consist of nitrogenous and non-nitrogenous compounds, or as the common, but not strictly accurate expression runs, "flesh forming" and "fattening constituents." We have seen that for the purposes of respiration, that is say, for combustion, maintenance of heat and force, the animal body requires a much larger proportion of carbo-hydrates and fats than of albuminoids, or flesh formers; an excess of these being always wasteful in the animal economy, because they are either unused and expelled as manure, or burnt up and made, so far, to play the part of the non-nitrogenous foods. It does not, however, follow that what is wasteful in the organism is really wasted; on the contrary, it is often a part of the feeder's aim to supply more nitrogenous food than the animal requires, in order that it may be expelled after passing through the digestive canal, and in its course undergoing a series of changes which render it specially fit for the food of plants. There are, in fact, three things to be thought of in feeding animals for early maturity—flesh, fat, and manure.

Laying on Flesh and Fat.—It is a popular belief—not, perhaps, put in any form of words, but clearly shown in the current practice—that in order to induce "laying on of flesh," an extra allowance of nitrogenous food must be given, while for fattening a larger proportion of oils and fats are necessary. This notion is supported by the common sense of mankind; but the physiologist feels bound to interpose a proviso. Besides the food elements, he remarks, there are certain conditions which influence the nutritive process. The animal is not quite a "tub" to be filled with anything which may be selected. It is true that food may be supplied of any kind, and in quantities which the feeder may deem sufficient for the production of flesh and fat in due proportion. It can, indeed, be calculated how much albuminoids, carbo-hydrates, and fat will be required every day to supply the waste of tissue; but it must not be forgotten that to get the food into the digestive organs is one thing, to insure that it shall be used in accordance with our intentions is another.

With all the success which we have gained in the cultivation of artificial qualities in our live-stock we have not yet got a race of animals which will lay on fat or flesh to order in exact proportion to the materials supplied in the form of food. Nature seems to make a firm stand here; and we shall best attain our object by paying a little attention to what she tells us about the conditions which affect the growth of these structures.

First, it is a law of Nature that the full measure of perfection can only be reached by any organ when its functions are called into exercise; and it is a fact within everybody's knowledge that the muscle organs are only to be improved and developed by regulated and constant use. The athlete can so order his mode of training as to cause one set of muscles or many to improve in size and power, and every trainer is aware that the one thing needful for bringing out the muscles of horse or man is exertion properly and carefully regulated, but never omitted. Suggest to the trainer that he can get a lame horse into muscular form by the use of flesh-forming food, or tell the disabled "oar" that his biceps will come out grandly on the day of the race if he will only keep his arm in a sling, and feed chiefly on albuminoids, with only a small proportion of fats and carbo-hydrates, and each will obey Dogberry's injunction to the letter, and "write you down an ass." But in truth the most asinine of asses would never dream of making such suggestions in regard to horse or man. It is only when food animals are in question that the most sapient of us will talk about feeding to make flesh in the case of stock which "in order to attain the earliest possible maturity must not quit their sheds summer nor winter; but remain indoors, placid and undisturbed." Are we not all of us perfectly sure that in such circumstances growth of muscle is impossible, however abundant may be the supply of flesh-forming food?

To all that has just been written about muscle growth, the reader may be supposed to object that we do not want to eat muscle—a hard, stringy, indigestible structure, not fit for civilised stomachs, but only proper to the limbs of race-horses, hunters, and athletes. We want tender juicy meat. And there is really something in the objection. We are most of us so accustomed to take our food in a state which renders mastication a mere matter of form, that if by chance we are brought in contact with a slice of real flesh from a six-year-old working ox—a steak which would delight the soul of a railway navvy, and give him "something to bite at"—and, we may add, good solid material to repair his muscles withal—we should decline to make our jaws ache, and risk the integrity of our feeble apologies for teeth—becoming more and more feeble in each succeeding generation, the dentists say—by engaging in the unequal contest.

In the estimation of the physiologist, muscle is flesh and nothing else; but we are fain to admit that the system of feeding for early maturity has introduced a new structure unrecognised by histologists, but most fitly called "baby meat"—a soft juicy mixture of fat and lean—by the eating of which we hope to produce large and strong muscles in our own bodies and limbs. Hope does, indeed, "tell a flattering tale."

Now the question arises, Can the "lean meat"—which we will no more call muscle—be increased in amount by any modification of the method of feeding? The answer can only be got from observation; and it is fortunate that the experiments at Rothamsted and in Germany have done much towards the solution of the riddle.

Even when an animal is at rest muscular action continues, and the muscles which are to be made into meat have to perform some work in breathing, in sustaining the body, in raising it, and in moving it from one part of a shed to another, if no more space is available to move in. In its least active state muscle is in the condition of "tonus," which is contraction; and therefore waste of its tissue is caused, and new material has to be supplied for its repair. Carbo-hydrates are largely required for this purpose, and some albuminoids; but it is impossible to blind ourselves to the fact that in fattening animals a very insignificant proportion of nitrogen is retained in the system, something like 96 per cent. being voided in solid and liquid manure. It would be premature to assert that there are no means of feeding for the production of a modified muscular tissue—or lean meat—in animals which do not undergo exertion; but, at present, we must be content to admit that the fatty constituents of the food have it all their own way, and that the great increase of the bulk of the carcase in fattening stock is due to the deposit of fat, not flesh.

One fact, which is very well known but often lost sight of in discussing systems of feeding, tells very decidedly against the idea that lean meat may be grown more liberally by the use of a larger proportion of flesh-forming food. The fact is that the food which is generally used for fattening—oil cake—is rich in flesh-forming substances. Linseed cake contains more than double the amount of albuminoids which exists in oats; and, judging from its chemical composition, it might be employed in training race-horses. Given to fattening oxen, however, it has the effect of adding to the amount of fat, for the deposition of which all the conditions of the animal's existence are favourable.

On a small scale, the "struggle for existence" occurs in the animal organism, between the two constituents of the daily food—the fats and flesh-formers. The fats are often in the minority, but that does not help the others. Fats find in the inactive state of the organism the occasion which suits them. Anything like action, quick breathing, rapid circulation, or strong muscular contraction, implies a large supply of oxygen, which is the natural enemy of fat—resolving it into heat, carbonic acid, and water.

But rest, slow movement of the blood, sluggish breathing—with no more oxygen than is actually wanted to sustain a placid life—are exactly the conditions which favour the increase of fatty tissue.

In the circumstances above described the flesh-formers are not much wanted, and therefore are not much employed. The little waste which has been going on in the scarcely used muscles is soon repaired, and then the sooner they are out of the way the better. And it is the duty of the excretory organs to see that they do not stop to block the way.

Outside the organism there is useful work for the rejected nitrogen in supplying food for plants; within the system it is at best useless and often injurious.

Statement of Results.—On behalf of the system of breeding and feeding for early maturity, for the market or the show-yard, the evidence, concisely stated, amounts to this:—

"Ten or twelve years ago the 'cracks' of the shows were always three years old, and sometimes older; now they are one year younger." Stirks may be kept steadily growing at the rate of 2½ lbs. per day, until at 20 months they reach the weight of 850 lbs. to 920 lbs: the dietary meanwhile being most liberal—including the milk which they suck for the first five or six months, grass, turnips, oat straw, daily allowance of cake, 2 lbs. to 5 lbs., with crushed grain added later on.

"Young animals, as everybody knows, feed better than old ones. The difference in food is very marked. Up to two years old the increase in weight may be on the average 2 lb. per day. Between two years and three years it amounts to a little over a pound per day, and in the course of the next year not more than half a pound of daily increase may be expected, according to American and English experience." The increase of weight is mainly due to the deposit of fat. The means of producing *lean meat* on the "early maturity" system not yet having been discovered.

Beyond the results stated, which seem finally to consist in making young animals big and very fat for the butcher or the fat stock show, has anything been gained? Surely, we may suppose breeders of pedigree stock to reply—much more has been gained. Look at our improved breeds, our Booths and Bates. What prices our bulls and heifers command at home and abroad! Exactly, but what makes a Duchess heifer worth a thousand pounds to an English or American stock owner? Precisely what makes a race-horse worth the same amount. The belief on the part of the purchaser that the animal and its offspring will win several thousands in stakes. Value in these cases is determined by fashion set, by-the-bye, not in Paris, but in New York. First, we have the "newest thing" in short-horns for the rage. Then Herefords come to the front; and now black polled cattle have their day. All this may be called speculation, or gambling, or anything else. It may amuse and help to pass away "the flagging hours" of this "unendurably long life." But what we want to insist on, most emphatically, is that the system has nothing to do with agriculture. And until it is shown that the effect of breeding pedigree stock is evident in the wide distribution of breeds of food-producing animals which are strong of constitution, capable of resisting disease, and above all of making good healthy meat in an economical way, it never will form a legitimate part of the Science and Practice of farming.

CHAPTER IX.

WHAT IS TO BE DONE?

Criticism on the "Show System"—Exhibition of Breeding Stock—Fat Stock Shows—Unprofitable Feeding—Possible States of the Animal Organism—Balance—Elaboration—Degeneration—Things which can be done—Breeding for Maturity—Necessity for Maturity and Soundness in Stock Animals—Management of Breeding Stock—Feeding for the Butcher—Proposed Modification of the Present System of Breeding and Feeding—Science and Practice in the Laboratory and on the Farm.

THE author began the last chapter with the perfectly honest idea of setting out the details of the "improved methods of breeding and feeding" in the most favourable light; but in looking over what he has written, he is conscious that the reader may finish with the notion that somehow everybody seems to have got wrong; and, if he is a visitor to the great agricultural exhibitions of stock at which the results of breeding and feeding are supposed to be seen at their best, he will ask if some account should not be taken of these grand gatherings, which are said to exercise so powerful an influence for good in agriculture. Well, something may be said on the matter, and it shall be said by practical men. This is what a writer in the *Field* recently said of the show system:—

"It may be stated that the fundamental principle of an agricultural society, in the ordinary acceptation of the term, is the show system. For now forty years at least—a period which covers the rise and progress of the majority of such associations—the popular idea has certainly been that an agricultural society exists mainly, if not entirely, for the purpose of promoting an annual show. This idea became intensified after the exhibition of 1851, when what might be termed the 'show mania' commenced. If, however, we look back a little, it will be found that the earlier promoters of associations for the improvement of agriculture had far more comprehensive ideas. It is only needful, for instance, to refer to Mr. Pusey's famous manifesto at the inauguration of the Royal Agricultural Society at Oxford on March 13, 1839, to see that in his mind at any rate the idea of a gigantic show was not present. His conception of the work of such a society as was then being started was rather that of a scientific organisation, similar to those already in existence in connection with botany, geology, and so forth. 'The collection of numerous minute facts by individual observers over a large surface' was evidently what he considered the primary work of a national society. But his mental attitude was one of receptiveness, and he concluded his address in these words: 'How we may best combine and order the separate efforts of our individual members—on the details of whose exertions, duly combined, in the various paths of our diversified art, to a common end, and carefully and honestly made known to our body, our slow but steady progress will mainly depend—must form the future subject of our common consideration.' Doubtless much work of the desirable character thus indicated has been carried out by the Royal Agricultural Society during its half century of life; but the overwhelming importance which has been attained by its annual exhibitions is rather indicative that the 'common consideration' of the society has not chiefly been given in the direction pointed out by Mr. Pusey.

"Let us, however, see to what extent the R. A. S. E. has to depend for the justification of its existence upon the show system. On reference to last year's cash account it will be found that, exclusive of the expenses of establishment and sundries, the society spent during 1884 the sum of £26,859 6*s*. 9*d*. Of this £22,285 1*s*. 10*d*. was expended on country-meeting accounts, in other words, on one or other of the shows. The remainder, £4574 4*s*. 11*d*. was spent on the Journal (which swallowed up rather more than half the amount), the chemical, veterinary, botanical, and educational departments, and on the inspection of farms. Thus five-sixths of the total expenditure went to the show. Take, once more, the Royal Society's nearest rival, the Bath and West of England Society. In its balance-sheet for last year I find, again excluding establishment expenses, a sum of £6332 13*s*. 3*d*. spent upon the show account, and no expenditure upon any other object whatever, except the comparatively paltry sum of £435 7*s*. 7*d*. upon the Journal.

"It would be unfair likewise to omit reference in connection with the Bath and West of England Society to the action taken by that society during the current year. In March last, at one of its council meetings, Mr. Knollys brought forward the following remarkable motion:—'That a special committee be appointed to consider whether the present expenditure of the funds of the society is that which is best calculated to promote the interests of agriculture.' This motion was remarkable in that it admitted the possibility of discussing even the sacred show system itself. As a matter of fact, I have reason to believe that it did result in a discussion upon the desirability of reducing the amount offered in prizes for stock. But for such a daring step the times were not yet ripe."

To the author's own knowledge these views have been in some form entertained, and in words more or less definitely expressed for some years past, by practical and representative agriculturists. Never better expressed, however, than in the words of Mr. Knollys' motion; and, if these words were echoed throughout the land, it is possible that the interests of agriculture might be looked at from a new point of view.

Agricultural shows are generally understood to be exhibitions of animals for breeding purpose. Exhibitions of fat stock have their place, however, in the show system, and are presumably conducted also on the principle of aiding the interests of agriculture.

A primary object of fat stock shows, we are told on high authority (the late Sir Brandreth Gibbs), is "to determine what *breeds* of animals and *methods of feeding* are calculated to yield most food for man from given quantities of food for live stock"—a perfectly proper object to aim at, but one which, asking the pardon of all promoters of fat stock shows, has never had the least effect on the practice of breeding and feeding. If promoters of fat stock shows meant what they say, they would never allow a prize to be awarded until the judges had seen the selected animals cut into joints by the butcher. That the main object, that of producing food of the best kind for man, has not been kept in view—to say nothing of having been gained—is the conclusion, not of the man of science, but of the practical farmer. Writing in this present year of grace, 1885, Mr. Evershed, as the exponent of practice as opposed to theory, says, under the heading of Flesh *versus* Fat:—"Another point awaiting decision is the kind of food to be given to the young animals. Unfortunately, our fat stock shows do not assist the solution of this most important problem, since their prizes encourage outside appearance, size, and weight, without regard to the quality of the carcase. They do not encourage breeders in the selection of heavy fleshed animals, nor feeders in the observance of such treatment as shall favour the production of lean meat instead of tallow." This is the practical view of the results of the approved methods of breeding and feeding animals for the show, the avowed object being to prove what breeds and what plan of feeding will produce the best food for man with the economical use of food for stock.

But if the system fails in one object, it is probably successful in the less patriotic but still laudable one of money-making. It pays! Does it? Let us hear some remarks from practical men, and first, Mr. Stratton, on the matter of finance:—

"I take a calf, to begin with, as being worth £2. I take it the animals shown in the 'young' class at Smithfield had at least two gallons of milk a day for nine months, and a great many have a good deal more; but as milk is worth something like a shilling a gallon in my part of the world, you will understand how it is that I cannot distinguish myself in that class. Two gallons a day for nine months equals 540 gallons, which, at 7*d.* a gallon, represents about £15. You cannot put the hay and roots down at less than 1*s.* a week, or £2 12*s.* a year; and then the cake, say, $1\frac{1}{2}$ lb. a day, amounts to 5 cwt.

at 8*s*., which is £2; making the total cost at the end of the first year £21 12*s*."

Mr. Stratton goes on to reckon that for the next nine months the animal will cost at the rate of 7*s*. 6*d*. per week, and at the end of the time the total expenditure will amount to £36 5*s*. He further assumes that the bullock will weigh 11½ cwt., or dead 44 score, which, at 15*s*. a score, will bring £33, showing a dead loss of £3 5*s*.

Again, let us hear what another practical man, the writer of "Live Stock Notes" in the *Mark Lane Express*, has to say about the results of feeding on the improved system for fat stock shows. He is writing of three Oxfordshire wethers, prize-winners at Smithfield:—"They were magnificent sheep—from the breeder's point of view perfect; they took the reserve number for the Champion Plate, as the best pen of sheep in the show: and what became of them? Well, they were last seen by us in a little shop in Lambeth Walk, lying down in the shop awaiting their doom, one week after the show had closed. After tens of thousands of people had admired them, congratulations had been passed between breeders, and prize-money pocketed, these wretched animals were about to be sold retail at fully 25 per cent. below the value of New Zealand carcases; and in respect of actual consumer's value, the two articles would scarcely bear naming in the same day." These are the practical views of the commercial advantages of the forcing system.

Up to the present we have not gained much by leaving the science of the matter, in order to get the evidence of the practical farmer, in favour of breeding and feeding for early maturity. After half a century of practice on improving the live stock of the farm, the exponents of the system tell us that the kind of food to be given to young animals for the production of lean meat instead of tallow—is "a point awaiting decision:" that the result of the improved practice of feeding is "mostly tallow:" that "young cattle are fed to the highest state of perfection—at a loss of £3 per head:" and that prize sheep, in regard to their value, "are not to be named in the same day with New Zealand carcases." It is almost time to let science have another word or two on the subject.

It may help us in our concluding reflections on Animal Life, if we can make out what are the states of existence which are possible under any form of management. Mr. E. Ray Lankester tells us that "we have as possibilities either balance or elaboration or degeneration,"—and again that "any new set of conditions occurring to an animal which renders its food and safety very easily attained, seems to lead as a rule to degeneration." That these sentences were written without any particular reference to the management of the live stock of the farm is quite certain; but they contain truths which the breeder and feeder have been forced by circumstances to illustrate over and over again in the course of his well meant but misdirected practice.

Without knowing or thinking anything about the three possibilities of the biologist, the practical breeder has aimed at the second—elaboration, and has hit the third—degeneration, the natural consequence of the new set of conditions, which art has introduced. This is the doctrine of the biologist, and experience has proved its truth. What, then, is there left to be said in favour of a system of breeding and feeding, which science emphatically condemns, and practice admits to have failed in its main objects of making good food for man, and giving some profit to those who are engaged in the business of making it? Positively nothing. If it were not the case that the system has become fashionable, and animals of favourite strains command a high but utterly fictitious price in the market, it would not stand for a day. Does any man with the average share of common sense entertain a doubt that the whole scheme of breeding for early maturity would undergo a radical change, if breeders were suddenly to become impressed with the necessity of producing a hardy, healthy race of animals, which would afford healthy and substantial food for man.

It is not easy, and it is the reverse of satisfactory, to have to admit that in the course of long years of steady effort we have been wilfully groping in the dark. But the sooner we get a glimpse of the fact, the less difficult it will be to retrace our steps; and there is no escape from the conclusion that if we mean to continue to cultivate the live stock of the farm, we shall have to proceed in a direction as nearly as possible, in some respects at least, opposite to the one which we have taken for many years.

Things which can be done.—It is related of Cuvier, the great naturalist, that he once entered a room in which some literary friends were engaged in compiling a dictionary, and had just defined the word "crab"—"a small red fish, which walks backwards." Cuvier was appealed to for an opinion as to the fitness of the terms. He replied:—"Gentlemen, the crab is not a fish, it is not red, and it does not walk backwards;—with these exceptions, your definition is excellent."

At this moment the author, speaking modestly, feels himself in the position of the great naturalist, to whom the breeders for early maturity appeal somewhat as follows:— "Sir,—This is our system, the outcome of years of practice. We breed from young, immature sires or dams, or both; often from families known to be tainted with hereditary disease, but of high pedigree. We shut up the progeny in sheds summer and winter, cram them with rich food, load them with fat to an uncomfortable extent, knowing that nobody will eat it, get them to a great weight at an early age, take prizes at shows, and sometimes get great prices in the market, but altogether we lose money by the business. Have you anything to suggest?" To whom the author would fain say, if he might say it without offence:—"Gentlemen,—It is wrong to breed from immature sires and dams, or from animals, whether old or young, with any constitutional disease or tendency thereto. The shutting up of young stock in sheds summer and winter is in every way objectionable. You should not cram animals with stimulating food to produce a lot of fat which no one will eat. Feeding stock merely to get prizes is not a legitimate object for the stock owner to aim at, but making good food for the people is;—with these exceptions, your system is excellent."

Breeding for "Maturity."—By omitting the word early before maturity we get rid of a difficulty which has barred the way for a long time. Under this "new system," which, by-the-bye, is as "old as the hills," we may still select the best type of animals for parents. Pedigree is not objectionable, but inherited feebleness of constitution or tendency to disease is. Therefore, soundness is the first qualification for the sires and dams of a healthy race. It must, however, be admitted that the carrying into effect of this principle would lead to the exclusion of some of our most valuable bulls and heifers, on account of the existence of the taint of scrofula (tuberculosis), a disease which is extending year by year in some of the cultivated breeds of cattle, and threatens serious results unless the greatest care be taken to avoid using infected animals for stock purposes.

Next in importance to soundness of constitution may be placed maturity. Until animals have reached the adult period, they are not proper subjects to breed from. The completion of permanent dentition is a fair test of maturity—say, three years of age for cattle and sheep, and eighteen months for swine. The objection that the breeder cannot afford to wait so long has nothing to do with the physiologist's view of the matter, and if the breeder decides that he cannot afford to do what is right, he has only to refer to the previous chapter to see how to do what is wrong with a high hand.

Management of Breeding Animals.—Having selected mature and healthy sires and dams, it may be presumed that the breeder will take some trouble about their management during gestation. Good food, fresh air, exercise, and protection from severe climatic changes, are the chief things to be attended to; at no time during the period of gestation can the dams be subjected to neglect or ill-treatment without danger. Errors in management at the early part of the period may not be visited on the animals until near the time of parturition, or at the time or after; and the pathologist who has to investigate outbreaks of disease in breeding herds or flocks often has to go back for some months to find out the causes.

Feeding for the Butcher.—Perfectly healthy stock, born of carefully-selected, mature, and sound parents, may, without injury to the breed, be forced to a condition of "early maturity," falsely so called; but the terms have a conventional meaning, which is understood. As the young animals are to be got ready for slaughter as quickly as reasonably may be, they must be fattened in the open pastures, if possible; but, in any case, fattened sufficiently to satisfy the demands of the butcher, and economically to meet the requirements of the farmer. There is something hopeful in the fact that agricultural writers are carrying on a crusade against what they rightly call the making of tallow; and if they only keep on long enough they will produce some effect, in spite of the temptation of the Prize System.

One condition might, without hardship, be imposed on all breeders and feeders of stock: animals which are fed for the butcher should on no account—by no afterthought—be used for breeding. Let the injury which is done by the excessive use of concentrated food be limited to the recipient, and we know the worst of it at once.

The attempt to reconcile the systems of breeding as nearly under natural conditions as domestication will permit with the forcing system of feeding can only gain a measure of success when breeding and fattening animals are managed on totally different principles. There may be some difficulties in the way, but the scheme is worth testing in practice. Its formula might be thus stated: "Secure mature and sound parents, so as to produce a healthy progeny; place these, if you like, under artificial conditions of life; damage their constitutions, for a time, and up to a certain point, then kill and eat them—and be thankful." This is a candid exposition of a scheme which, if fairly and honestly worked out, will preserve a very large proportion of our herds and flocks from degeneration, by keeping them as far as possible apart from those surroundings which have already been known to exert a steady and constant influence in favour of the "Survival of the Unfittest."

It must be obvious that in the course of the preceding remarks on breeding and feeding, only a mere sketch of a large subject has been attempted. Some serious errors, the effect of which are likely to reach farther than is at present suspected, have been pointed out; and certain corrections suggested for the consideration of the practical man. But it forms no part of the writer's object to enter upon matters of detail. Experiments in breeding and feeding are still being conducted by competent observers, and the results are published week by week in the agricultural journals. It is the fashion among farmers to sneer at the idea of learning their business out of books. Will they accept—as kindly as it is meant?—the hint that an hour or two devoted to the records of the observations of men who are doing their best to solve the problems in agriculture, the answers to which are yet unguessed at, will not finally be put down to the score of "mis-spent time"?

Breeding and feeding are matters of practice; but it is only where the mental state is one of "sweet simplicity" that the practical man will urge that the facts of science are hurtful rather than helpful to him in his work. It is quite true that the value of food stuffs can be tested only by feeding animals on them; because, while the analyst can tell the exact amount of dry nutritive matter, fibre, and ash, he cannot decide how far the digestive powers of different animals may vary, until the test is applied; but it must surely be useful to the farmer to begin with a knowledge of the chemical value of the foods which he intends to use before he tests their feeding value on the animals.

It is time, in these days of Agricultural Colleges and School Boards, that farmers should see the absurdity of a sneer against the "jargon of science." It would be better if plain words could always be used to express facts and notions, but some technical terms can hardly be dispensed with; and the rising generation of farmers are bound to master them, as they are bound to master many other things, if English farming is to hold its own against the world.

Perhaps the slow progress of agriculture is in a great measure due to the fact that it has always been looked upon as a matter of practice as distinct from science—about as great a blunder as could well be made. As well call the work of the chemist and physiologist, practice as distinct from science. The agriculturist is engaged in carrying on experiments in chemistry and physiology on a grand scale, and in laboratories—of an extent which may be indicated not by square feet, but by thousands of square miles. The real difference is that in the small laboratories the workers cannot afford to waste the brief hours of their lives in doing exactly what has been done for centuries before them, or in varying their experiments by mixing a lot of things together just to see what will happen. In scientific work absolute precision is demanded: nothing is put into a test-tube without a definite idea of a result which may be expected to occur. The scalpel of the practical physiologist never moves the smallest fraction of an inch without absolutely ordered intention; he knows exactly what he is seeking, and, if he fails to find it, can understand, and therefore remove, the causes of his failure.

Work in the larger laboratories of the farm should certainly be conducted on the principles which regulate work in the smaller fields of labour—that is to say, with absolute precision; with a full knowledge of the composition and properties of the material used and their relation to the matter in hand, and, above all, with a perfectly definite idea of the object which is to be gained.

The farmer, for instance, intends to cultivate certain plants. What relation do their habits bear to the climate and soil? What food do they require, and how is it to be given? Is the plant to be fed economically, that is, without waste of food? or is the nutritive material to be cast widely over the ground or buried in it, leaving the plant to seek it as best it may?

On the other hand, the practical breeder selects stock for breeding animals for the butcher, for the dairy, for wool or mutton. He feeds with the view to flesh and fat, milk or wool, and incidentally for manure. Does he know from the experience of the past or the work of the present, all the facts that bear upon his practice—the composition and properties of all the materials which he uses, and their exact relation to the several objects at which he aims in his experiments? To come closer home, does the worker in the larger laboratory know as much of the laws of science and practice of farming as he might learn by giving a few weeks' time to the careful study of the half dozen little hand-books of the Farm Series? No. Then he has no business in the workshop at all; and if he does not get blown out of it into small pieces, he may thank his stars that he is not working with explosive substances.

The conclusion of the argument is, that the farmer who is not a scientific worker—using the term in its ordinary sense—does not work at all; he plays—and either wins or loses by chance.

At the beginning of this chapter the question was asked, "What is to be done?" In reply the author has ventured to suggest some changes in the management of the live-stock of the farm, not involving any radical alterations in the system which the fashion of the day decrees. He has not asked for much, and is even prepared for less than he has asked, remembering, as he does, the Turkish proverb:—

"Blessed is he who expects nothing, he shall never be disappointed."

CHAPTER X.

DECAY AND DEATH.

Life consists on the Correspondence of the Functions with their Surroundings —Environment—Death occurs when the Correspondence is Disturbed—Molecular and Somatic Death—Death beginning at the Heart, in the Lung, the Brain, in the Blood—Life and Death equally associated with Activity.

Death—the universal fact—not doubted by the most contentious of disputants. Even the agnostic knows that stern reality. Life, as we have seen, is defined in a formula for the convenience of thinkers. The words used do not cloak our ignorance: they honestly express it. All we know about life—they say—is that it is a series of phenomena manifested by living beings. Life is the correspondence of the changes which we know are always going on in the living organism, with the external conditions—the environments—that is, heat, electricity, air, light—everything by which the living being is surrounded —in the midst of which it lives and moves.

So long as the organism, whether it be the living mass of transparent jelly (bioplasm), or the highest form of animal or plant, continues in correspondence with its environment, it lives—might indeed, for anything which we see to the contrary, live for ever. "Perfect correspondence," says Mr. Herbert Spencer, "would be perfect life: were there no changes in the environment but such as the organism had adapted changes to meet, and were it never to fail in the efficiency with which it met them, there would be eternal existence." These words are worth thinking over—one at a time if need be—until their full meaning and force are grasped. They contain well-nigh all that is to be said on the subject of life, and leave very little to be added to express all that can be said about death. Living substance lives so long as it is in perfect correspondence with its environment. Life ceases when the correspondence is interrupted, and this state of cessation of vital actions we call death.

Eternal existence of the living organism is not a fact—we may safely affirm this, because we see organism cease to live—and therefore we may conclude that changes *do* occur in the environment which the organism has *not* "adapted changes" to meet. This is a very simple piece of logic. But we are, perhaps, hardly prepared to learn that the organism is so arranged with regard to its environment, that the two get, more or less, out of correspondence the moment they begin to correspond.

If we were invited to witness the spectacle of an animal partly dead and partly living, we should probably rush to see something so startling, and consider ourselves the victims of a hoax if we were shown a horse or man in an ordinary state of life and health. Yet there is no joke, but a serious reality before us. At the moment that vital action begins in the germ some of the living particles get out of correspondence with their surroundings, cease to live, and are thrown or dissolved, and probably absorbed as food by the living particles which remain. During the whole period of the development of the embryo, living substance is constantly dying from want of nutriment, or other derangements of its external relations, and, after birth, so long as life lasts, living matter in the organism is always dying and living again, until at length the entire cessation of correspondence with the environment leaves no more living matter to die.

Complete, or what pathologists call *somatic*, death, is only an extension of the death of the particles of living structure—*molecular* death—which is one of the results of vital activity in all living beings.

Dr. Masters* has explained how death in plants occurs in various parts of the organism, while other parts live on. Death may begin at the root of the plant, or in its leaves, and when the dead organ is essential to the life of the plant the whole of the organism dies.

Death in animals also may commence in the vital organs of the body, or in the blood, or the tissues, and its completion depends on the relation which the dead part holds to the rest of the organism. The eye may be out of correspondence with light, and the ear with the waves of air; the animal may be blind and deaf, but this molecular death of certain "end organs" of nerves does not affect the life of other organs.

A limb, or part of it, may suffer from "changes in the environment" which it has no "adapted changes to meet." It may, for instance, be subjected to intense heat or cold, or crushing weight, and this failure to meet the changes efficiently results in disturbance of correspondence, and life ceases. But this molecular death does not necessarily extend. It may, and if the dead part remain long in contact with the living it will; but the dead mass may be

* "Life on the Farm—Plant Life." By Maxwell T. Masters, M.D., F.R.S. Bradbury, Agnew, & Co., 9, Bouverie Street, London.

purposely removed, or the living textures in contact with it may throw it off, by exerting their own vital force and interposing a disconnecting film of new tissue between the dead and the living.

Death beginning in a vital organ leads to systemic or somatic death, because all other vital organs are dependent on it and on each other. Death of the heart stops the circulation of the blood, on which the maintenance of all the functions of life depend. Death of the lungs arrests the supply of oxygen, without which the blood fails to act as a stimulus to the heart. Death of the blood means death carried to the remotest parts of every tissue; and death of the nerve centres implies the cessation of the evolution and distribution of force by which organic action is sustained. These several modes of death may be considered without any feeling of solemnity or pity in reference to the animals of the farm, whose lives we hold so cheaply that life or death in them is a mere matter of money loss or gain to us.

Death beginning at the Heart.—Cessation of the heart's action may be sudden, from a shock to the nervous system, or gradual, from the failure of its power to contract. In the first condition, the heart after death may be found either firmly contracted, with its cavities empty of blood, or it may be in a relaxed state, with its cavities full of blood which it has not been able to expel, owing to the loss of the muscular irritability which causes it to contract under the influences of the stimulus of the blood flowing into it.

Gradual loss of the heart's power to contract occurs under different circumstances. Loss of blood is one direct cause of the failure of the heart to contract, the obvious reason being that the withdrawal of the fluid diminishes its bulk, so that the quantity conveyed to the heart is not sufficient to distend the cavities and induce contraction. It is evident that the rate of decrease in the force of the heart's action will be in proportion to the rapidity of the flow of blood from the wounded vessels.

Wasting diseases—to which farm animals are liable—some kinds of poisons, deficient quantity or bad quality of food, excessive and continued exertion and exposure, are among the causes which gradually affect the energy of the heart contraction, and ultimately lead to its cessation.

Death beginning at the Lungs.—When the organs of the respiratory system and their uses were considered, enough was said to prove that air is a necessity of life. The blood must get a supply of oxygen or it ceases to stimulate the heart; therefore, death of the lungs means not only stoppage of breathing, but also of the circulation and death from asphyxia, which means stoppage of circulation—pulselessness.

The circumstances under which death begins at the lungs are numerous. Disease of the lung tissues may be associated with obstruction to the passage of blood, by the blocking up in the vessels. Effusion of fluid into the cavity of the chest may cause pressure on the yielding lung structures, and produce the same result as excessive distension of the stomach with a gas—a common occurrence in cattle and sheep—and may cause the organ to press on the diaphragm, and push it forward into the chest and thus diminish the size of the cavity, and prevent the necessary expansion for inspiration. In bronchial diseases the accumulation of mucus may stop the entrance of air into the smaller tubes and air cells, or breathing may be suddenly stopped by spasmodic closure of the opening at the top of the windpipe, or by the entrance of fluids in the act of swallowing—an accident which occurs now and then in giving a drench—or by the severing of the part of the brain (medulla) from which the nerves of respiration arise.

There is some difference of opinion among pathologists as to the exact way in which death is caused by stopping the breath. One view is that the impure, that is, unaërated blood is sent through the heart from the lungs over the body, acting as a poison to the brain and causing unconsciousness and death. The other view, which is supported by observations of the state of the lungs in strangled animals, is that the small capillary vessels of the lungs contract and stop the passage of blood from the right side of the heart, so that it never gets back to the left side at all, and, therefore, is not sent over the body. In other words, the circulation is stopped in the lungs, and death beginning in them quickly arrests the life of the whole organism.

Death beginning in the Blood.—In many forms of malignant diseases the living matter which the blood is carrying for the repair of wasted tissues dies so rapidly that the dead material cannot be got rid of and new living substance obtained quickly enough to enable the blood to carry on its work of life, and it ends by doing the work of death, presenting dead particles instead of living to the tissues through which it circulates.

It is not difficult to see that when the blood-stream is charged with effete matters, somatic death must soon follow from the mere absence of the means for sustaining life.

The animals of the farm are particularly susceptible to diseases of the blood which end in the death of its constituents. Cattle-plague, splenic fever, black quarter, purpura, and scarlatina are maladies in which this condition of the circulating fluid is frequently observed. But death of the blood may occur, independently of any specific disease, from the introduction of organisms which have the power of inducing putrefactive fermentation. Experiments have proved that this condition may be induced by small particles of septic matter, and the blood thus contaminated itself acquires poisonous properties, and acts as a septic ferment, if introduced into the system of another animal, often causing death in a few hours.

Death beginning at the Brain.—Modern physiology has proved that death of a considerable portion of the substance of the brain is not of necessity followed by death of the whole body, and the flock-master may have met with cases among his stock which illustrate the truth of this modern doctrine. The very well-known parasite, the hydatid, which infests the brain of "giddy sheep" sometimes encroaches so much on the brain-substance that, when the worm is removed the skull seems to be almost empty; and yet the animal has continued to live and perform all the functions of life, even, perhaps, has fed well enough to be fit for the butcher. It appears, indeed, that death beginning at the brain only results in somatic death, that is death of the whole organism, when the nerve centres die, and especially when death extends to the origin of the nerves which go to the heart, and the muscles concerned in the act of breathing. Owing to this fact, parasites, hydatids, and tumours may exist in the brain or in its substance for some time without causing any great disturbance, or even indicating their presence until their increase in size leads to pressure in the roots of the nerves; and then loss of consciousness and cessation of circulation and respiration follow.

Death beginning at the brain may be sudden, or the result of a violent shock inflicted upon the organ, which at once arrests the distribution of nerve force, and leads to the immediate stoppage of the functions of organic life. This form of death occurs from accident, and is illustrated in the ordinary method of slaughtering animals by the pole-axe.

With the cessation of vitality in the organism the story of "Animal Life on the Farm" ends. The wonderful apparatus of the living body which we have been engaged in examining in respect of its structure and uses becomes, when dead, not what it seems to the eye of the ordinary looker-on, but the centre of new changes, which will end in the conversion of the complex tissues into simple compounds of carbon, oxygen, hydrogen, nitrogen, sulphur and phosphorus, which will be again organised by the plant world, and used to support a new race of animals. And thus the "World goes round." Life is incessant action. In sleeping and waking there are going on development, growth, waste, repair, change, and decay. Death, whatever it may mean, does not mean rest for the body, but rather full liberty to every particle to seek new forms and combinations. In Life and Death the law is, ceaseless activity. There is no such thing as Rest in the Universe.

GLOSSARY.

Albuminoid.—Relating to or containing albumen. An organic compound of oxygen, hydrogen, carbon, and nitrogen, with sulphur and phosphorus; represented in the white of an egg.

Bioplasm.—Living plasma. Living matter in the most simple form (*see* PLASMA).

Capillaries.—Minute hair-like vessels, intermediate in situation between the arteries and veins.

Chyle.—A milky fluid containing dissolved albuminoids and minute particles of fat. The fluid is formed during intestinal digestion, and is absorbed by the lacteals.

Diaphragm (Midriff or Skirt).—The muscular partition which divides the cavity of the chest from the abdomen.

Diastase.—A vegetable principle, allied in general properties to gluten, which is produced in the germination of barley and other seeds, and converts starch into gum and sugar.

Epithelial.—Relating to epithelium—a layer of cells on the surface of the skin, and mucous and serous membranes.

Follicle.—A minute tube or secreting cavity, as the hair follicles of the skin.

Irritability.—A property of muscle which renders it sensitive to the action of the stimulus which causes the muscle to contract.

Lacteals.—Minute vessels arising in the small intestines, which take up the milky fluid (chyle) and carry it to a larger vessel (the thoracic duct), whence it flows into the large veins near the heart.

Lymph.—A colourless fluid, consisting of the plasma of the blood, with colourless corpuscles.

Lymphatics.—Small vessels which arise in the tissues in all parts of the body, and carry back to the blood the excess of lymph which the tissues do not immediately require.

Medulla.—The spinal marrow, especially the expanded part of it at the base of the brain. Also the fatty substance, the marrow of bones.

Mesentery.—A fold of serous membrane covering the intestines, and attaching them to other organs and parts.

Mucous Secretion.—A thick tenacious transparent fluid, which is secreted by mucous membranes—for example, the membrane of the nostrils.

Œsophagus (Swallow or Gullet)—A muscular canal or tube, with a lining of mucous membrane extending from the pharynx to the stomach, for the passage of the food.

Pepsin.—An organic substance existing in gastric juice, which is secreted by the peptic glands of the stomach. Pepsin in solution with dilute acids acts on albuminoids, and renders them soluble.

Peptones.—Albuminoids rendered soluble by the action of pepsin in solution with dilute hydrochloric acid.

Pharynx.—A muscular pouch or cavity at the back of the mouth, forming the entrance to the œsophagus. The pharynx is lined by mucous membrane continued from the mouth.

Physiology.—The science which treats especially of the functions of living beings, and of the properties of organic bodies.

Plasma.—The tenacious, plastic, liquid portion of the blood, in which the corpuscles (red and colourless) float.

Ptyalin.—An albuminoid compound in the saliva (spittle), which acts like diastase, converting starch into gum and sugar.

Sebaceous.—Like suet. The term is applied to the secretion which is known as "the yolk" in the wool of the sheep, and is very abundant on some parts of the skin. The substance is of an oily nature, and is secreted from numerous small glands and follicles in the skin.

Serous Membranes.—So called because they secrete a thin yellowish fluid like the serum of the blood. The fluid is called serous fluid.

Tuberculosis (Consumption).—A disease in which a deposit occurs in the form of small nodules (tubercles) in the lungs, lymphatic glands, and other organs of the body.

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